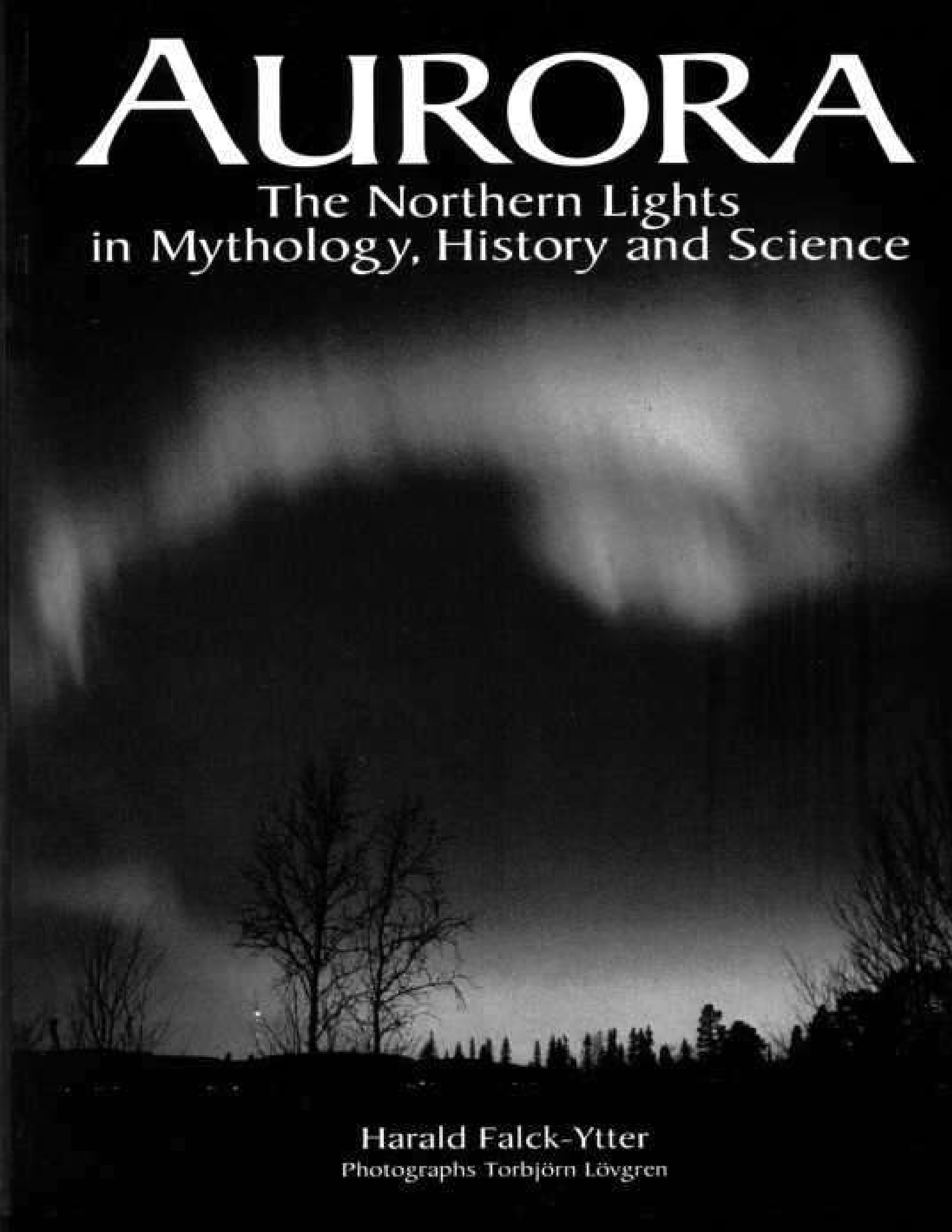
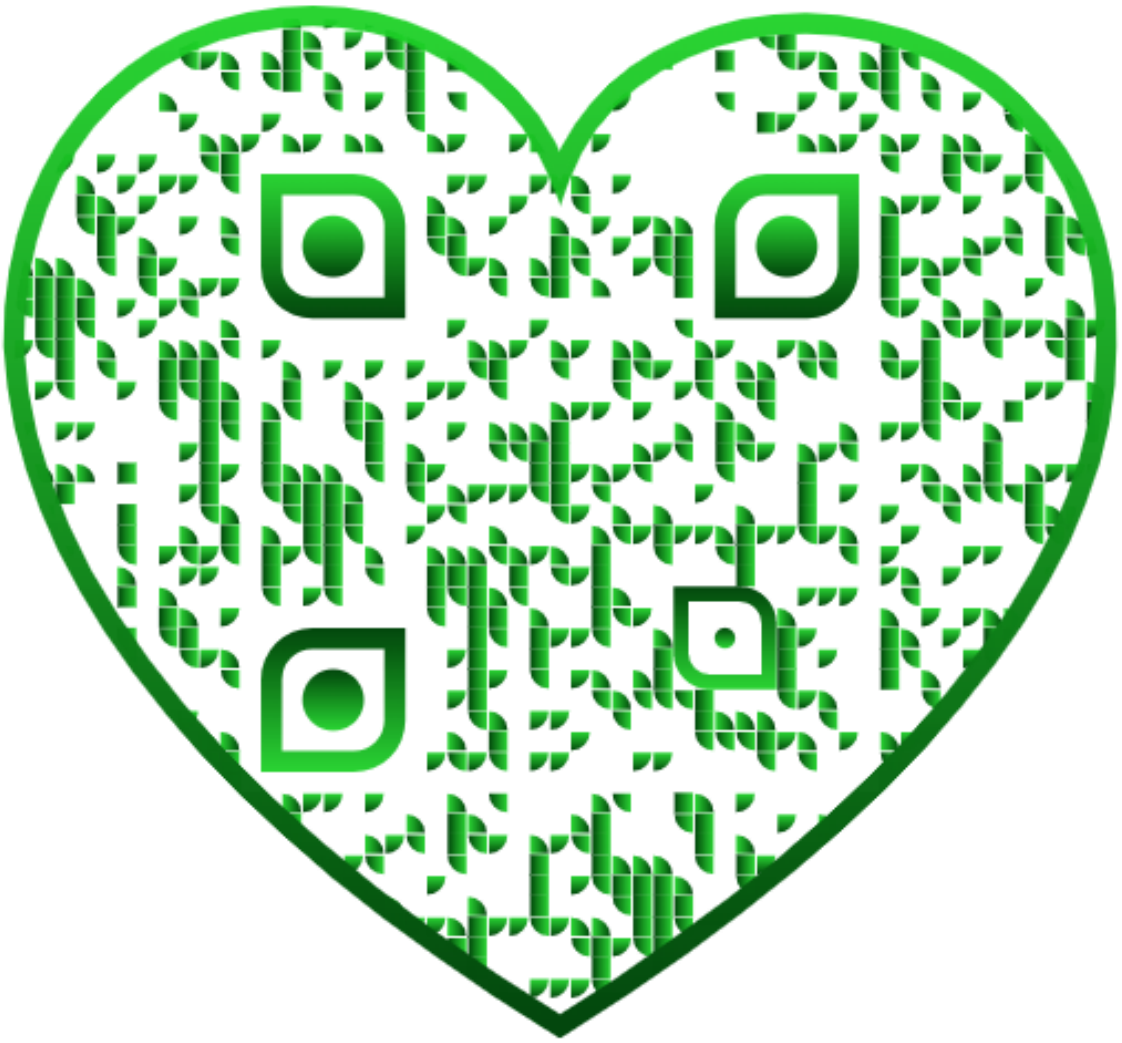
AURORA

The Northern Lights in Mythology, History and Science



Harald Falck-Ytter
Photographs Torbjörn Lövgren



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Harald Falck-Ytter

Photographs by Torbjorn Lovgren

Bell Pond Books

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1. The Northern Lights

The mysterious aurora appears in the sparsely populated polar regions of the North during the dark season of the year. Aurora borealis in Greek, dawn of the North - is the scientific name of this colourful light phenomenon in the northern hemisphere; in the southern hemisphere it is called the southern dawn, aurora australis.

Closer, scientific observation of these natural phenomena began in the nineteenth century, linked to the advance of explorers and adventurers into uninhabited Arctic and Antarctic regions. What had been an everyday experience for Inuit, Lapps and other indigenous peoples throughout the centuries became a fascinating and revolutionary discovery for the scientifically minded peoples of western culture. For, in the darkness of the polar night, a hitherto unseen light glowed before their eyes, divulging veils of colour which, in their intensity and transparency, had never been found anywhere else. They resembled nothing ever seen on earth, except perhaps in dreams. It was a long time before it was understood how this flowing light and wafting colour could arise without the presence of sunlight. Numerous theories and hypotheses were put forward concerning the polar lights, only to be refuted or carried to absurdity. It was only possible to penetrate this mystery when the twentieth century allowed a wider view of the cosmos, thus leading the human spirit to new explanations.

The first exact, modern accounts of the aurora are from the courageous self-sacrificing discoveries of the nineteenth and early twentieth centuries. One of the most distinguished exponents of the northern lights was the Norwegian polar explorer, Fridtjof Nansen (1861-1930). He constantly tried to portray the strange moving phenomenon of the aurora borealis in words and drawings. In his diary, during the drift of his ship Fram into the Arctic pack-ice he wrote:

> I went on deck this evening in a rather gloomy frame of mind, but was nailed to the spot the moment I got outside. There is the supernatural for you - the northern lights flashing in matchless power and beauty over the sky in all the colours of the rainbow! Seldom or never have I seen

> the colours so brilliant. The prevailing one at first was yellow, but that gradually flickered over to green, and then a sparkling ruby-red began to show at the bottom of the rays on the under side of the arch. And now from the far-away western horizon a fiery serpent writhed itself up over the sky, shining brighter and brighter as it came. It split into three, all brilliantly glittering. Then the colours changed. The serpent to the south turned almost ruby-red, with spots of yellow; the one in the middle yellow, and the one to the north, greenish white. Sheaves of rays swept along the side of the serpents, driven through the ether-like waves before a storm wind. They sway backward and forward, now strong, now fainter again. The serpents reached and passed the zenith. Though I was thinly dressed and shivering with cold, I could not tear myself away till the spectacle was over, and only a faintly glowing fiery serpent near the eastern horizon showed where it had begun. When I came on deck later the masses of light had passed northward and spread themselves in incomplete arches over the northern sky. If one wants to read mystic meanings into the phenomena of nature, here, surely, is the opportunity.]

About a decade later there was a race for the South Pole between the Norwegian Roald Amundsen (1872-1928), and the British explorer, Robert F. Scott (1868-1912). In Scott's personal notes, made during his expedition in the Antarctic and published posthumously, there is a vivid account of the aurora australis:

> The eastern sky was massed with swaying auroral light, the most vivid and beautiful display that I had ever seen - fold on fold the arches and curtains of vibrating luminosity rose and spread across the sky, to slowly fade and yet again spring to glowing life.

Woodcut by Fridtjof Nansen from an observation on November 28, 1893.

> The brighter light seemed to flow, now to mass itself in wreathing folds in one quarter, from which lustrous streamers shot upward, and anon to run in waves through the system of some dimmer figure as if to infuse new life within it.

> It is impossible to witness such a beautiful phenomenon without a sense of awe, and yet this sentiment is not inspired by its brilliancy but rather by its delicacy in light and colour, its transparency, and above all by its tremulous evanescence of form. There is no glittering splendour to dazzle the eye, as has been too often described; rather the appeal is to the imagination by the suggestion of something wholly spiritual, something instinct with a fluttering ethereal life, serenely confident yet restlessly mobile.
>
> One wonders why history does not tell us of `aurora' worshippers, so easily could the phenomenon be considered the manifestation of `god' or `demon'. To the little silent group which stood at gaze before such enchantment it seemed profane to return to the mental and physical atmosphere of our house.2

To the attentive observer, the aurora always appears as something totally fresh. The limitless diversity of its forms and waning movement continually challenges one to describe and understand the phenomenon anew. This was particularly true before photography was developed. The first successful photograph of the polar lights was taken in 1892 by a German physicist, Martin Brendal (1862-1939)

Prior to this, in the days of adventurous wanderings on foot, a modern Marco Polo travelled over vast areas of the earth as a news correspondent, reporting his multifarious impressions in detail. He was Bayard Taylor (1825-78), the American poet and writer. Taylor saw the aurora borealis in northern Scandinavia and had the good fortune to also see a corona which appears as the epitome and culmination of the northern lights' revelation:

> I opened my eyes, ... looked upward, and saw a narrow belt or scarf of silver fire stretching directly across the zenith, with its loose, frayed ends slowly swaying to and fro down the slopes of the sky. Presently it began to waver, bending back and forth, sometimes slowly, sometimes with a quick, springing motion, as if testing its elasticity. Now it took the shape of a bow, now undulated into Hogarth's line of beauty, brightening and fading in its sinuous motion, and finally formed a shepherd's crook, the end of which suddenly began to separate and fall off, as if driven by a strong wind, until the whole belt shot away in long,

drifting lines of fiery snow. It then gathered again into a dozen dancing fragments, which alternately advanced and retreated, shot hither and thither, against and across each other, blazed out in yellow and rosy gleams or paled again, playing a thousand fantastic pranks, as if guided by some wild whim.

We lay silent with upturned faces, watching this wonderful spectacle. Suddenly, the scattered lights ran together, as by a common impulse, joined their bright ends, twisted them through each other, and fell in a broad, luminous curtain straight downward through the air until its fringed hem swung apparently but a few yards over our heads. This phenomenon was so unexpected and startling, that for a moment I thought our faces would be touched by the skirts of the glorious drapery. It did not follow the spheric curve of the firmament, but hung plumb from the zenith, falling, apparently, millions of leagues through the air, its folds gathered together among the stars and its embroidery of flame sweeping the earth and shedding a pale, unearthly radiance over the waste of snow. A moment afterwards and it was again drawn up, parted, waved its flambeaux and shot its lances hither and thither, advancing and retreating as before. Anything so strange, so capricious, so wonderful, so gloriously beautiful, I scarcely hope to see again.3

The Danish painter, Harald Moltke, accompanied various research expeditions to Iceland and Finland in 1899 and 1900. At Akureyi, on the Eyja Fjord, North Iceland (66° N) and at Utsjoki on The Tana River in Finnish Lapland (70° N) he observed the aurora. He produced a set of lithographs which still rank as the most significant artistic renderings of the aurora. The following eight pictures are reproductions from this collection.

Early attempts at explanations

As a result of polar expeditions and travels in northern Scandinavia, news of these phenomena spread, and scientists attempted to explain them. To begin with, however, this met with no success at all. The nature and complexity of the phenomena proved too intricate for the thinking at that time. Thus, for many decades, details of numerous individual observations were collected, which could not be understood by research.

To begin with, the dynamics of auroral movement were difficult to grasp. The beginning and end of a display were never discernible, nor could anyone determine when and where the aurora would be seen in the sky. The moving, dramatic climax of an auroral appearance was characterized by a profusion of barely imaginable, diversified forms, that disappeared unexpectedly. Arcs, bands, curtains, veils, drapery, rays and clouds filled the sky in quick succession, and each subsequent revelation of the aurora was different. No known laws of cause and effect encompassed this continual and unpredictable change of form. Even those best acquainted with the phenomenon remained spellbound by the uniqueness and novelty of a significant display.

Initially, the enigma of emerging light and colour in the absolute darkness had a profoundly moving effect on the human soul. White light and the whole spectrum of the rainbow unfurled in an ever-fresh profusion of colour: an impulsive red emanated from a shimmer of peaceful, soothing green; a bright red polar light diffused across the sky could grip the soul with panic; yellow rays and depths of blue and violet stirred up all kinds of emotion in the observer. Yet no one could explain where this exuberance of colour came from.

For a long time, there was controversy over the height at which the aurora appeared, and it was soon acknowledged to be impossible to estimate the height and breadth of its source. At best, it was assumed that the aurora was a meteorological phenomenon and therefore connected with air currents and weather.

The question then arose: Where does the aurora appear geographically? The higher the latitude the clearer and more widespread the aurora was. However, it was then discovered that the light and colour diminished significantly in the region of the poles and disappeared entirely in their immediate neighbourhood.

The view that the aurora was related to meteorological phenomena led to the search for its relationship with annual seasonal changes. But such a connection was difficult to establish. The aurora is only visible when it is dark, and so when summer sunlight predominates throughout the night in northern Scandinavia, the aurora cannot be seen. Only when darkness

descends again in the autumn, is its appearance possible.

Archetypal descriptions

Following observations made over many decades, it was demonstrated that there was a distinct daily, auroral cycle, at least in northern Europe. When the typical development of the aurora is described it is the result of lengthy and detailed observation. The vivacity and uniqueness of each individual display actually hinders the perception of the phenomenon described.

First of all, there is the auroral arc which usually runs from East to West across the whole sky, and normally to the North in northern latitudes. There are often several arcs; each one typically one to ten kilometres wide, although its length may stretch over one thousand kilometres. It is difficult for an observer to ascertain these dimensions visually because the lower edge of the aurora is most often at an altitude of one hundred kilometres or more, and the forms manifest themselves several hundred kilometres above that. The distance of the aurora from the observer is, therefore, generally several hundred kilometres.

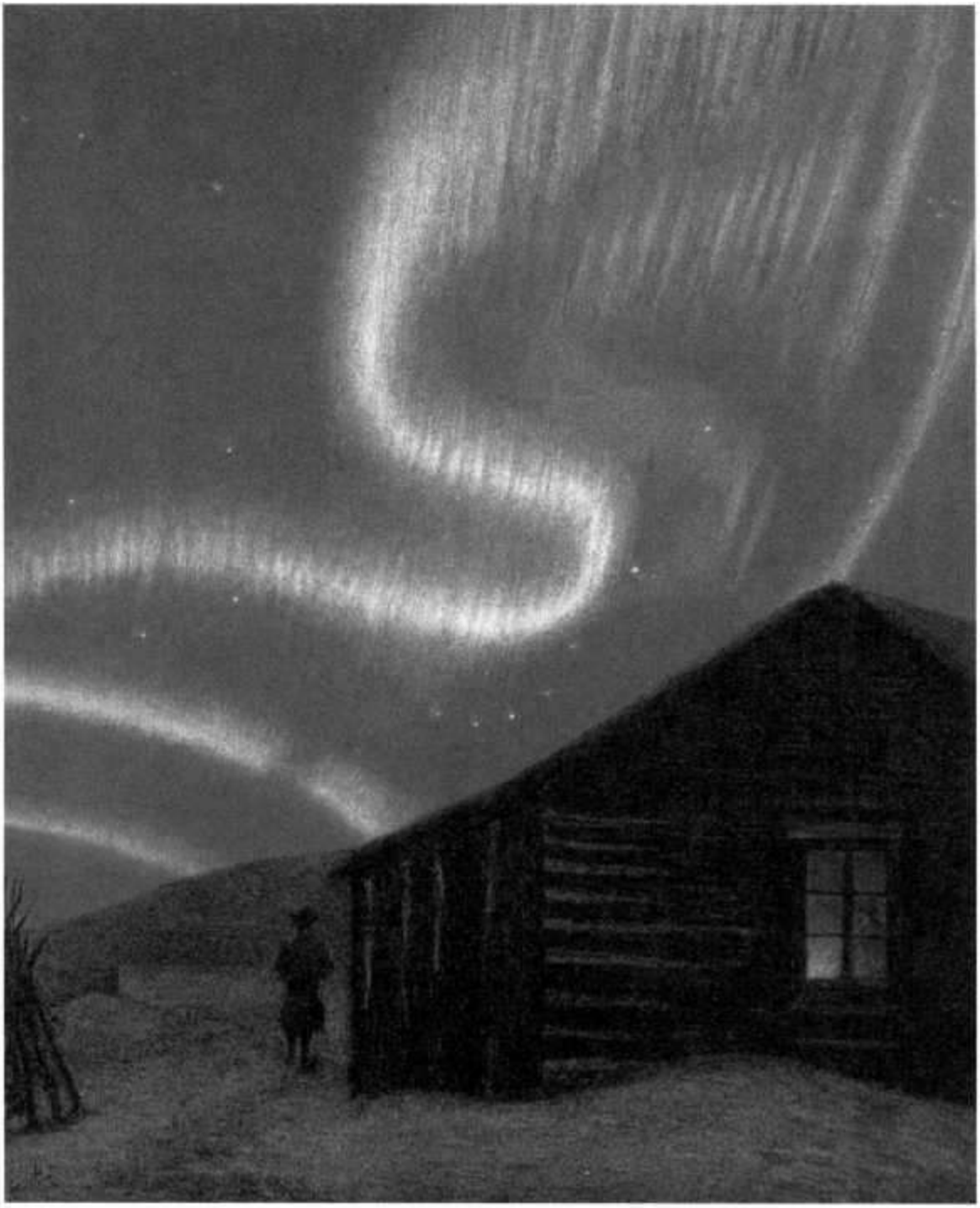
Ordinarily, the arcs mainly appear as a white diffused light in which no other configurations are yet present. They are static to begin with and can remain so for several hours, and are most often visible in the early hours of the evening. Gradually a pulsing and flowing movement evolves within the arcs, which appear as a vertical structure of rays, taking on a green or yellow-green colour as the auroral display develops. When this structure begins to move, other colours appear, such as red. Seen from close by, the individual rays seem like pleated curtains of light, or vertically flowing curves of loosely folded, curtain-like bands. These images appeared to a Russian cosmonaut as abundant pil lars of light when he flew through them. The initial amorphous arc is transformed into a pulsating pleated band, only appearing as a structure of rays from a great distance. As the coloured arc now climbs up into the zenith waves of motion enter its vibrating folds. If these vibrations increase the band becomes a hanging curtain.

In the meantime, the activity of the aurora increases considerably, as does its exuberance of colour. The curtain-like band then begins a second phase, often in late evening. The band's movements result in overlapping vibrations

within the arc, which may develop into spirals. A pulsating energy enters the arched band, causing powerful oscillations and the formation of free shapes. The band is thus broken up and independent bodies fill large portions of the sky. Veils, curtains, spirals, draperies and rays produce a multifarious moving drama in the sky. The aurora enters its third and most active phase, in which the vault of the heavens can turn red. Seen from the south, the various curtains and draperies usually hang as if slanting towards the centre of the northern lights. Seen from the north, or more precisely, from the regional centre of the northern lights, the curtains hang towards the observer, who can therefore stand directly under the various curtains and draperies, which all then run vertically parallel. The effect of perspective thus brings a central point into view around which all the forms group themselves.

It is only with difficulty that the human eye can take in the spatial depth of these huge dimensions; the formations appear as if arranged round a middle point, allowing the image of a crown corona to arise. A corona also takes on a varying structure, and its formation constitutes the ultimate development of the third auroral phase. Thereafter, the assorted activity declines; individual fields of colour spread out like clouds over large parts of the sky, and may remain like this for about an hour. At this stage, a new arc often arises.

In northern Scandinavia, there is, for the most part, a basic rhythm which runs from early evening until nearly midnight. However, other regions exhibit a different pattern. The development of the individual phases may also take quite a different form; the above description is a kind of basic pattern that is seldom seen. The aurora evolves so arbitrarily and variably that it is difficult for the observer to perceive typical junctures of development and many researchers into the aurora do not, therefore, recognize such stages. Yet, in the nineteenth century, there were already accounts that clearly described such phases without any awareness of an archetypal pattern.



The Austrian polar scientist, Karl Weyprecht, (1838-81) led a research team to the Arctic Ocean from 1872 to 1874, discovering the land named Franz Josef Land, after the then reigning Austrian Emperor. During the expedition, Captain Weyprecht experienced the aurora borealis, including a corona formation:

There in the south, low on the horizon, lies a faint arc of light. It looks as if it is the upper edge of the dark segment of a circle; only the stars that shine through it in untarnished brilliance convince us that the darkness of the segment is an illusion created by the contrast. Slowly, the arc increases in intensity and rises towards the zenith; it is perfectly regular, both its ends almost touch the horizon and move out towards east and west the higher it rises. No rays are seen in it; the whole consists of a fairly homogeneous light substratum of magnificent, delicate colouring; it is a transparent white with a pale greenish shade, not dissimilar from the whitish green of a young plant which has sprouted without sunlight in the dark. The moon's light appears yellow beside this delicate colour, so pleasing to the eye, so beyond verbal description, and given by Nature only to the polar regions, the Cinderella of creation, as if by way of compensation.

The arc is broad; it is perhaps three times the breadth of the rainbow and its much sharper edges stand out glaringly against the deep darkness of the Arctic night sky. Its light outshines the stars in unclouded brilliance. Higher and higher rises the arc, a classical calm lies over the whole phenomenon; only here and there does a wave of light dance across from one side to the other. Over the ice it grows lighter, individual clumps of ice are distinguishable.

It still stands at a distance from the zenith and already a second arc detaches itself from the dark segment to the south and by and by others follow it. They all climb towards the zenith, the first one has already crossed it and sinks slowly towards the northern horizon, losing its intensity. Now there are arcs of light spanning the whole of the heavens; seven are in the sky at the same time, but then their intensity is only low. The further they go towards the north, the paler they become, and finally they then disappear altogether; but, they often all return across the zenith and are extinguished as they come.

Only seldom, however, is the development of the northern lights so calm and regular.

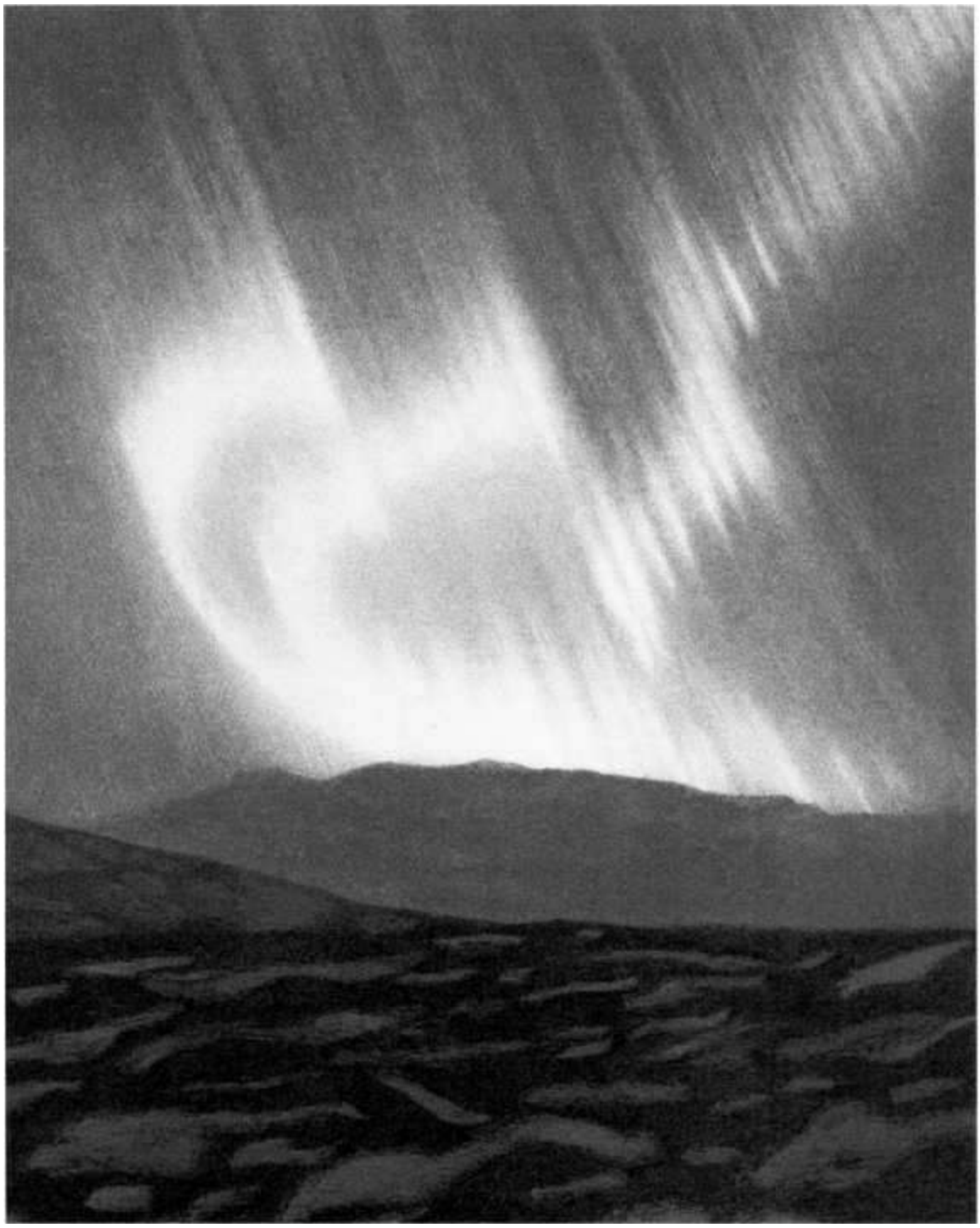
Waves of light flit continually through the band in undulating movement throughout its extent. At one moment they are running from right to left,

at another from left to right; they appear to cross over each other, depending upon whether they appear in front of or behind a spiral. Now the bend is coiled up along its whole length; it has arranged itself in graceful folds; it almost appears as though the wind, high up in the atmosphere, were pursuing a secret game with the wide flaming pennant whose end loses itself far away on the horizon.

The light grows ever more intensive; the waves of light follow one another ever faster; on the upper and lower edges of the band appear rainbow colours; the shining, delicate white in the middle is bordered by a narrow strip of red below, green above. In the meantime, out of one band two have merged; the upper one approaches ever nearer to the zenith, now rays begin to stream out in the direction of that point in the vicinity of the zenith towards which the south pole of a free-moving magnetic needle points. The band has almost reached it, and now, for a short time, there begins a magnificent display of rays centred on the magnetic pole, an indication of the intimate relationship of the whole phenomenon with our Earth's mysterious magnetic forces.

... Yet another configuration. Throughout the day, bands of every possible form and intensity have cruised around in the sky; it is now eight o'clock in the evening, the hour of greatest auroral intensity. For the moment, there are only isolated pencils of rays in the sky; only in the south, close to the horizon lies a faint band that we hardly notice. All at once, it rises suddenly; it spreads out towards east and west; light waves begin to dance through; individual rays climb up towards the zenith. For a short time, it remains stationary, then it is suddenly animated. The waves of light run from east to west, the edges take on an intensive red and green, and dance up and down; the rays shoot faster into the heights, they become shorter; everything rises, nearer and nearer they come to the magnetic pole. Faster and faster the waves follow upon each other; they already tumble over one another, they cross each other, they run over each other; in a wild race the rays vie with one another to reach the pole first; but they are no longer individual rays they are whole bundles that race simultaneously upwards into the whole southern heavens in a wild rush. And now they have all reached the point they all strove for and rays are shooting up and down in all directions, north and south, east

and west. Nature presents us with a firework display whose magnificence surpasses the boldest imagination. We listen instinctively; such an exhibition strikes us as unthinkable without deafening noise; but a silent calm reigns, not the slightest rustle reaches our ears. It has grown bright over the ice. Yet already everything is fading. With the same incomprehensible speed with which it came it has disappeared again. Only there in the northern sky a band now stands; the light-waves dance slowly through; across the ice the dark night has again wrapped everything in its cloak.



> That was the aurora of the coming storm, the northern lights in full glory. No colour and no brush is able to paint it; no words can describe it in all its grandeur.4

The colour illustrations in this book, try to show this archetypal

development, both in lithographs by the Danish painter, Harald Moltke (1871-1960), and in the series of photographs by the Swede, Torbjorn Lovgren.

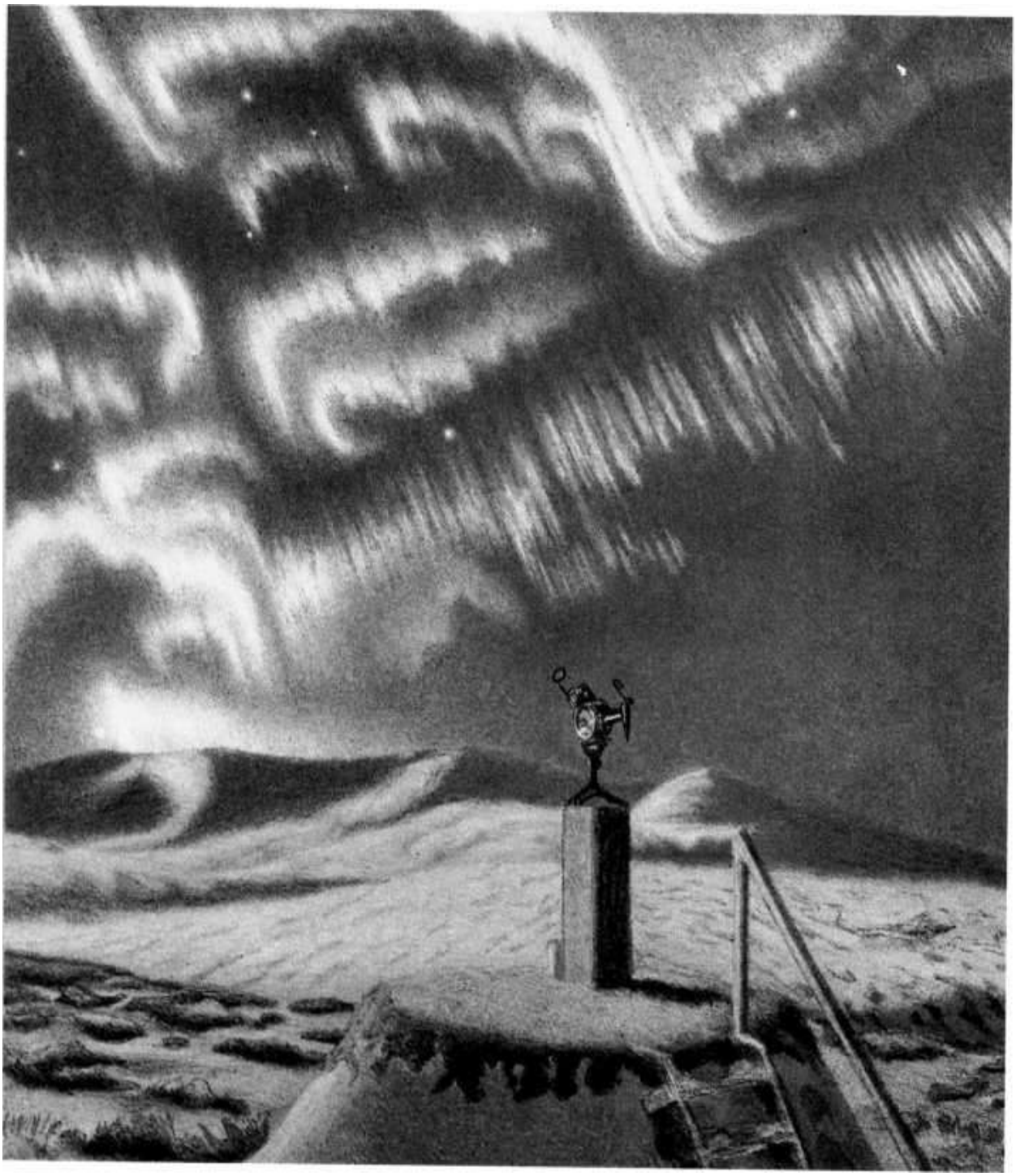
The elusive height and sound of the aurora

The behaviour of the aurora in different regions and at various times is not yet fully explained. Past accounts often speak of an aurora that reached down to the earth's surface. The measurements possible today have not been able to confirm such proximity to the earth. Despite this, descriptions of the aurora's immediate closeness to the earth are continually turning up. Thus Dorothy J. Ray writes:

> The aurora never has been measured closer to the earth than 35 miles [55 km], and there is doubt whether it actually gets that close. But dozens of lonely northeners have watched their only guest, the aurora, wrap a mountain with its flimsy nets. I have too, scientists to the contrary.
>
> The Brooks Range in Alaska one night in late August was as bright with the aurora as if it were dawn. After two years in the North I had learned to view these dazzling displays with equanimity, but this one differed from others as much as hamburger from a T-bone steak. The aurora had just accomplished the impossible. It had come down to meet the earth just a few miles from me. The top of the highest mountain in the vicinity ... was completely submerged in an auroral gauze.
>
> When it lifted a few seconds later, I assumed I had been the victim of an Arctic mirage. But that contrary aurora flickered and dipped over and around the mountain top for more than 20 minutes, settling now and then with uncanny precision on its pinnacle. What I had witnessed was impossible, according to science. The sensible explanation is that it was reflections of light on skitterish clouds, or some other atmospheric condition. Others who report similar experiences have no doubt seen the same kind of phenomenon.5

Numerous traditions, particularly those of the Native Americans, Inuit and Lapps, as well as later accounts, tell how the northern lights are often

accompanied by various low but distinct sounds - hissing, crackling and piping - however, no modern equipment has been able to verify this. For a long time it was a completely unsolved problem. Many of the concomitant, acoustic phenomena can be explained psychologically; the intensive and grandiose light and colour display evokes sounds in the observer's psyche and hearing, but they are subjective and only heard internally. Nevertheless, many of the descriptions point to an external, objective phenomenon.



Though perception of sound occurred simultaneously with the auroral display, thoughtful consideration concluded that the sound could not come from the display. At the average height of the aurora (100 km/60 miles) hardly any sound emerges, and if it took place at a significantly lower level, the distance would still be so great that concurrent incidents of light and sound could not be experienced. Recently, attention has been drawn to electromagnetic tensions that are discharged over the surface of a landscape. These can be measured and have also been demonstrated, for instance, on

dogs in northern Canada, whose hair stands on end and gives off crackling sparks in the presence of strong auroral light. Since auroral displays are related to tensions in the earth's electric field, their discharge could give rise, in certain regions, to acoustic phenomena similar to the crackling below high-tension pylon cables.

However, some also believe that the character of the aurora has changed, as a statement by the German traveller, naturalist and statesman, Alexander von Humboldt (1769-1859) poignantly expressed: `The northern lights appear to have become less noisy since their appearance has been more precisely registered.'

2. Aurora in Mythology

In the region around Ottawa, Ontario, Canada's indigenous people possess a living tradition about the origin of the northern lights:

> The demigod Nanahboozho created the world and human beings. After the creation was complete and people had received knowledge and experience in managing their environment, Nanahboozho passed on to his permanent abode in the North. But before he left mankind, he promised to look after them and follow their lives. As a sign of his protection he would from time to time light great flares whose reflection would be visible to mankind in the skies.'

For these populations the northern lights are reflections of Nanah- boozho's flames, experienced as a continually active, living reverberation of the creation; they exist in the earth's surroundings and do not intervene directly in nature.

This tradition clearly expresses the northern lights as a flaming image - a witness to the creative forces that today still manifest the infinite diversity of the creative processes. From this point of view, the tradition of Ottawa's indigenous people is understandable and obvious. Other native inhabitants experienced rather the mediating role of the northern lights; like an emissary who can take up a personal relationship. A native of the far north-west of Canada narrates:

> When I was a boy, people respected the northern lights as messengers of our spirits. People also said that some men and women can bring the northern lights down and make them obey their commands. You only have to walk outside, rub your hands together and whistle, then the northern lights will come down and sing and dance for you. When I was a young man I tried it once and it worked.2

This personal approachability of the aurora borealis is mentioned in many accounts. Although the aurora in its isolated great height is very distant, it appears, again and again, to lend its ear to human beings, hence its portrayal

as an emissary.

Unborn and departed souls

A conception connected with the aurora is its relationship with unborn souls and children about to be born. One of the oldest traditions comes from ancient China in about 2600 BC `The mother of the Yellow Emperor, Shuan-Yuan, Fu Pao, saw a big lightning circulating around the Su star of Bei-Don (Ursa Major), with the light shining all over the field. She then became pregnant.'- Several elements in the account point to the aurora. The star mentioned is situated in the north. During a thunderstorm no stars are to be seen because the clouds cover them. The term lightning is used as a substitute or metaphor for the northern lights, however, a lightning flash does not move in circles.

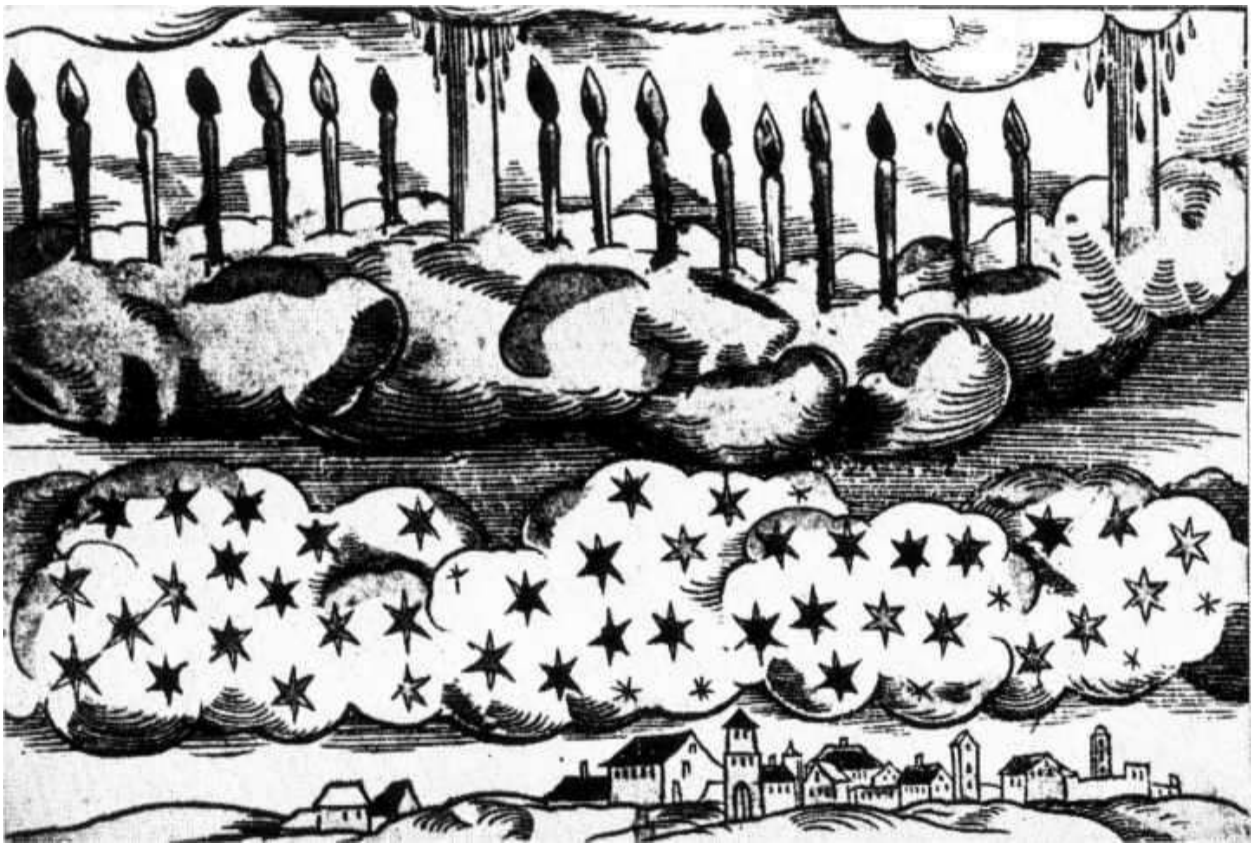
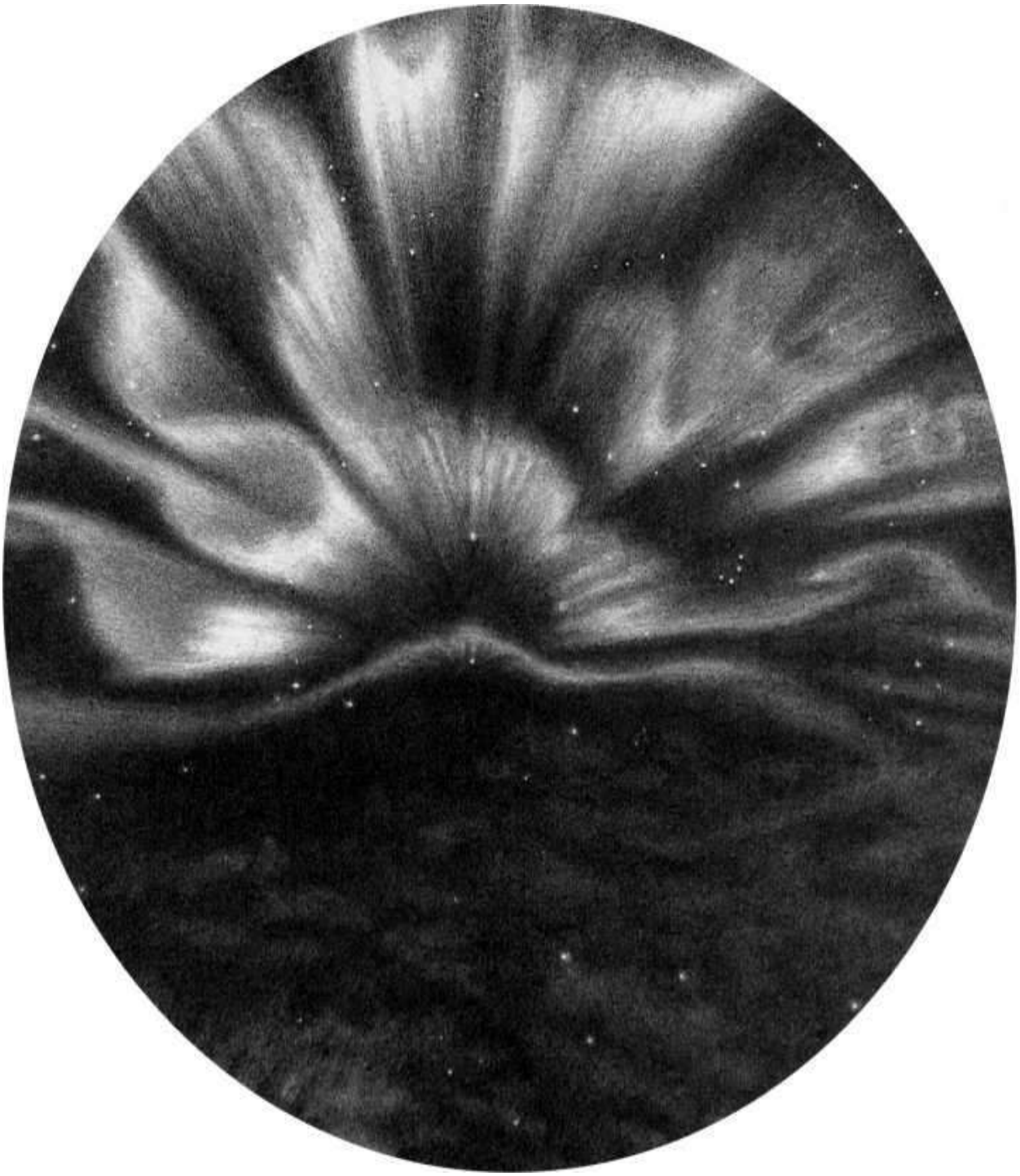


Figure 1. An early attempt to portray the aurora, as seen in Bohemia in 1570.



The influence of the aurora at birth is often emphasized among other peoples. So an indigenous Siberian tribe, the Chuvash, have a god called Suratan-Tura, which roughly translates as `the heaven-sent birth.' The same name is also used for the northern lights and when they appear then, according to the Chuvash tribe, a son will be born to Suratan-Tura. They also

believe that women in childbirth experience relief by means of the northern lights,4 and playing children are often seen in their imagery of the aurora.

By far the most common tradition, however, is the widespread idea that the dead are present in the aurora borealis, an idea that is portrayed in many different ways. One example of this belief comes from the Inuit in Labrador:

> The ends of the land and sea are bounded by an immense abyss, over which a narrow and dangerous pathway leads to the heavenly regions. The sky is a great dome of hard material arched over the earth. There is a hole in it through which the spirits pass to the true heavens. Only the spirits of those who have died a voluntary or violent death, and the raven, have been over this pathway. The spirits who live there light torches to guide the feet of new arrivals. This is the light of the aurora. They can be seen there feasting and playing football with a walrus skull.
>
> The whistling crackling noise which sometimes accompanies the aurora is the voices of these spirits trying to communicate with the people of the earth. They should always be answered in a whispering voice. Youths and small boys dance to the aurora. The heavenly spirits are called selamiut `sky-dwellers,' those who live in the sky.5

In this tradition, it is notable that not all the deceased are seen in the auroral sphere. Those seen are involved in an activity; to help the new arrivals. A ball-game motif is common and corresponds to a desire to transform the aurora's dynamic movements into a perceptual image.

Greenland

The Danish explorer Knud Rasmussen (1879-1933) collected traditions of the Igluik Inuit in Greenland who recount a similar tale to that of the Labrador Inuit:

> The dead suffer no hardship, wherever they may go, but most prefer nevertheless to dwell in the Land of Day, where the pleasures appear to be without limit. Here, they are constantly playing ball, the Eskimos' favourite game, laughing and singing, and the ball they play with is the skull of a walrus. The object is to kick the skull in such a manner that it

always falls with the tusks downwards, and thus sticks fast in the ground. It is this ball game of the departed souls that appears as the aurora borealis, and is heard as a whistling, rustling, crackling sound. The noise is made by the souls as they run across the frost-hardened snow of the heavens. If one happens to be out alone at night when the aurora borealis is visible, and hears this whistling sound, one has only to whistle in return and the light will come nearer, out of curiosity.6

Lapland

Accounts of both life and death are also interwoven in the aurora traditions. In a narrative of the Skolt Lapps in northern Finland both these elements are seen together. Robert Crottet, a researcher into the culture of these people, retells a story in this connection. The gist of it is as follows: Although it is summer, the dark hut of the oldest man in Lapland is illuminated by a lamp filled with light from the aurora. The old man holds prisoner three rays of the northern lights in a bottle. They are three deceased souls who would rather live imprisoned on earth than free in heaven. A youth has followed the old man. Both are now in the old man's hut, and the youth perceives that he is locked in. With the help of the deceased souls, the old man wants to transfer the youth's soul into his own old body. He will thereby continue to live for he is already almost two thousand years old. As the deceased are freed from the bottle and plunge their hands into the youth's body, the northern lights descend to earth - despite the midnight sun's presence - 'suddenly, a gigantic blaze of light flames over the sky. The northern lights spread out their rays as though a huge flower had opened its petals. One of its petals rushes through the hut window. Then the hands are pulled back out of the youth's breast. He gives vent to a cry of joy.'

The northern lights thus take the three dead souls back to themselves and free the youth. When he talks about his experience, no one believes him. Therefore the youth asks his fiancee, `How is it, then, that you believe that the dead protect us in the northern lights?'

The content of this tradition reveals a peculiar situation: the northern lights, forced down to Earth, have the power to carry out a complicated vital process. Here, the motif is the conservation of life through an exchange of souls. Simultaneously, the ability of the northern lights to penetrate daylight

is surprisingly revealed; it is always present, even in summer, and can hinder the dark practices of human beings. In this way, auroral forces are projected into the terrestrial realms of good and evil.

Native Americans

One of the most impressive traditions is to be found among the Native Americans of the Pacific north-west coast. They tell how a particular person manages to penetrate the strange realm of the northern lights, to have experiences there, and to return to earth. They narrate the following story:

> Chief M'Sartto, Morning Star, had an only son, different from all others in the tribe. The son would not play with other children but would take his bow and arrow and be away for days. Curious as to what mischief his boy could be up to, the Chief one day followed him. His journey progressed and all at once a queer feeling filled the old Chief, as if all knowledge was floating away from him. His eyes suddenly closed and when they were opened he found himself in an extremely light country with no sun, moon or stars. There were many people about, and they spoke a strange language which he did not understand. The people were engaged in a wonderful game of ball which seemed to turn the light to many colours. The players all had lights on their heads and wore very curious belts called Menquan or Rainbow belts. After many days of searching for his son the old Chief met a man who spoke his language. The man had also travelled by chance to this strange new country and knew of the Chief's son. When he was brought to his son the Chief saw him playing ball with the others, and strangely enough the boy's light was brighter than any there. When the game was ended, the old Chief was introduced to the people and honoured by the Chief of the Northern Lights; two great birds were ordered to be brought forth, K'che Sippe by name. On these birds the two dwellers of the Lower World returned home from the Wa-ba-ban, the land of the Northern Lights, following the Spirits Path, Ket-a-gus-wowt or Milky Way. Again all knowledge was erased from Chief M'Sartto. When they arrived home, the Chief's wife paid no notice that they were gone because she was afraid that they would never return and was very relieved. So it is that those very few who travel to the Land of the Northern Lights do not remember their

remarkable journey. But the Chief's son remembers and travels there often.?

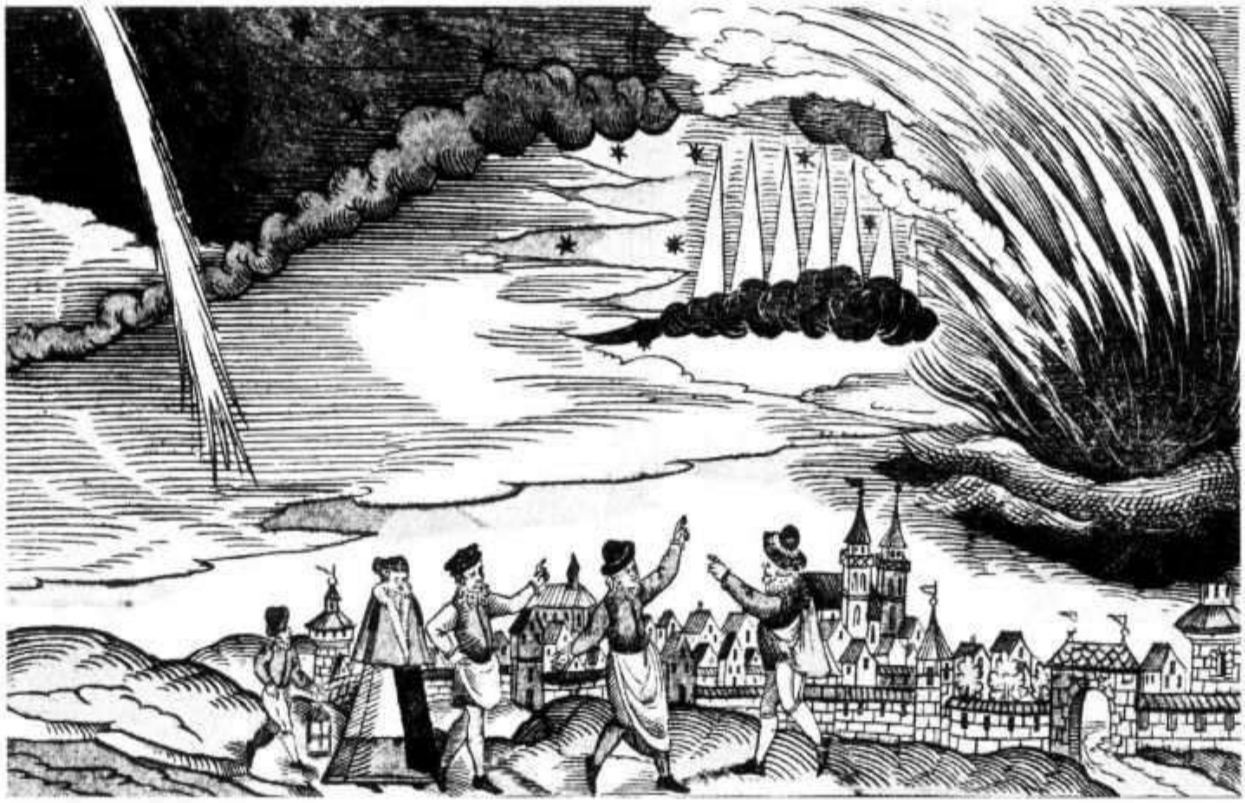


Figure 2. In Nuremburg, Germany, the aurora was seen in 1591 and in this engraving is portrayed as fire.

In this calm, matter-of-fact account there is a historical connection to the soul-journeys of the north Asiatic shamans. Furthermore, here there seems to be an aspect of the future, when it will be possible for man to consciously cross the threshold of birth and death. This will happen by means of an initiation taking place in the symbolic realm of the aurora borealis.

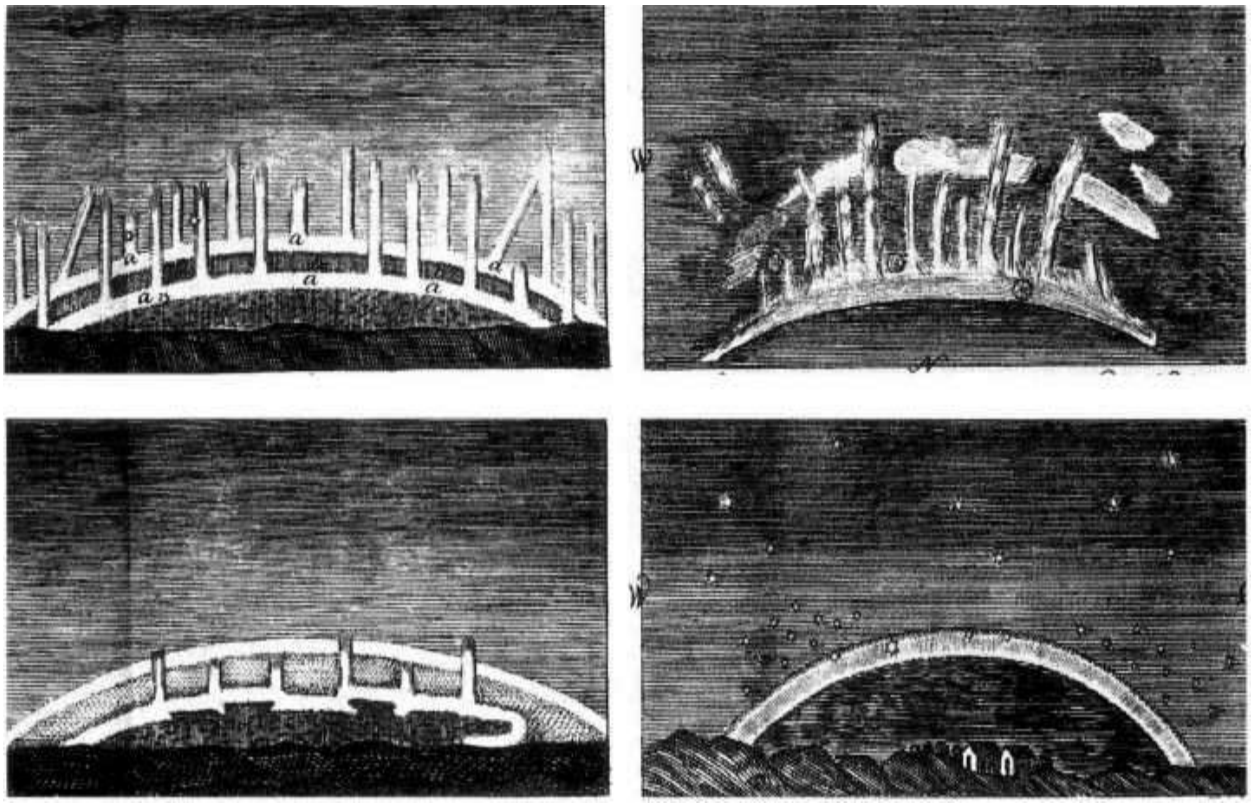


Figure 3. Illustrations for an essay on the aurora which appeared in the Acta So- cietatis, Copenhagen 1745. The aim was to portray the arc and rays of the aurora.

The Greeks

The Greeks also knew of a legendary people who lived in northern Europe. They spoke of the Hyperboreans, whose name means beyond the North (the north wind). Like the inhabitants of the auroral world described by the Native Americans and Inuit, these people lived in a mild, sunny and fertile land, free from the weight of earthly destiny. They lived for one thousand years, and only when they tired of life did they die a quick and painless death. When winter came to Greece, the sun-god Apollo moved to the land of Hyperborea. This mythical event presents a peculiar puzzle: why does Apollo, who is akin to light, move into the darkness and cold of the northern polar night?

In the traditions encompassing ancient clairvoyance and the mystery centres, the Greeks and their initiates not only perceived the external darkness and the physical cold of the terrestrial North, they experienced how this part of the earth was permeated by supersensory light and heat. Together with the

sunlight, these forces constitute essential elements of Apollo's being. In the Hyperborean realm, supersensory light is transformed into visible illumination, and occult heat into the external colour flow of the aurora.

For the Greeks it was a spiritual sequence of events to see Apollo during the dark season in the part of the earth where the supersensory sun-forces were manifest in the aurora borealis. In southern Europe during the winter the sun is essentially at rest, but in the North, in old Hyperborea, it is roused and spiritually active with the aurora.

Kalevala

The step from occult light-forces to life itself is but a small one, and is intimated in the birth-myths of the far North. The phenomena of the active life-realm are represented in the Kalevala; an epic of the FinnoUgrian peoples, revived by Elias Lonnrot (1802-84). At the heart of this epic there is a mysterious being the Sampo - created by the divine-human smith Ilmarinen in dark Sariola, the land of the North. In the epic, the creation of the Sampo is described as follows:

> Forged with cunning art the Sampo, And on one side was a corn-mill, On another side a salt-mill
>
> And upon the third a coin-mill. Now was grinding the new Sampo, And revolved the pictured cover, Chestfuls did it grind till evening, First for food it ground a chestful, And another ground for barter, And a third it ground for storage.8

This miraculous entity not only grinds substances but also creates them. The sphere of life to which this pertains points to human beings: flour is generated by the living, it is nourishment for human beings and the foundation of daily bread. It leads towards the life processes of the physical human body. Salt is taken from the mineral world and is a vital addition to nourishment, necessary for the development of the human will. The words of Christ: `You are the salt of the earth'9 make clear this life process in the soul. Money emphasizes our interdependence on each other's work. These interconnections are the basis for new, spiritual activity. They are the life processes of body, soul and spirit which are brought forth by the Sampo as it

grinds.

The Sampo is covered by a many-coloured lid which revolves. In Finnish it is called Kirjokansi which signifies the vault of the heavens. The same word is used later' for the heavenly spheres. A spark of fire falls `through six spangled vaults of heaven'. The word Kansi forms part of the Finnish word for the vault of the heavens (Taivaankansi) and Kirjo means `colourful, embroidered, rune and script.' Thus imaginatively expanded Kirjokansi could mean: the revolving vault of the heavens filled with brilliant stars and coloured northern lights, in which numerous runes, written signs and forms are visible. Whoever could interpret the `many-coloured lid' would be able to read the heavenly script. What did these early peoples read in the Sampo?

In prehistoric times, the Finno-Ugrian peoples migrated from Russia's interior into the Baltic region, to about latitude 60°. They settled along the coasts and also explored the far North. In their migrations from south to north and back again, these peoples discovered the threshold and limits of latitude 60°. Chapter 6 describes the particular characteristics of the threshold of latitude 60°, which forms the frontier between the two mythical realms and lands of the Kalevala, Northland and Kalevala. The content of the epic is the contentious drama in the relationships between the life-forces that takes place on this frontier.

To the Finno-Ugrian peoples this planetary occurrence must have evolved into a mill-grinding image that is able to produce and use life substances for human existence - Sampo in the Kalevala. Since an earthly human being cannot comprehend this image, and finds it even more difficult to acquire the life-forces, the Sampo had to be created by a divine-human creator. Gods and men had to fight in order to bring the Sampo south. As a consequence, it was broken into pieces and the largest piece sank in the sea. Nevertheless, splinters floating on the water contained the forces to create a new realm of life for human beings, which became the new land of Kalevala.

The Kalevala describes impressively, precisely and consistently how `the many-coloured lid' is brought to the North again, either in bits or whole. For the present, it remains in the possession of the hostile Northland powers, and the heavenly vault, with the many-coloured flaming northern lights, still remains intact, but unattainable, in the heights. A continuation of the epic

might be the spiritual penetration of Sampo and the `many-coloured lid.'

Theodor Doubler: herald of the northern lights

When the poet Theodor Doubler (1876-1934), wrote his epic on the northern lights, Das Nordlicht, the planetary dimensions of the northern auroral oval had just begun to be grasped by scientists. Doubler was the first to interpret the auroral oval as a living organism, as well as an expression of the Pentecostal state of the earth.

In the landscape of his homeland, then Austrian Istria, Daubler had not seen the aurora, and there is no evidence that he ever saw, nor even attempted to see the northern lights. His descriptions bear the amazing mark of an intuitive perception of astonishing precision. He wrote about the origin of this spiritual intuition in the foreword to Das Nordlicht:

> ... the earth concealed within itself yet a great amount of sun which was united with us in opposition to gravity and wanting to return to the sun ... Especially there, at the poles, where the night is deepest, longest, particularly powerful! A shining embrace of sun redeemed from earth and the sun in the sky brings the aurora to the months-long night at the poles. The earth longs to be a shining star again. My private cosmogony had attained its completion.
>
> The aurora can show us the way [to a final mediating sun]. It brings us closer to the archetypal light.
>
> ... The following, however, remains as the task of humanity - to realize the future of the earth through the northern lights! We proclaim, the earth will shine once more, but the peoples are responsible that this dark star will some day become the brightest of all. I i

A brief example from the section `The Sleeper,' echoes the immeasurable silence of the polar night. Against this undisturbed background of tranquillity the northern lights appear in particularly spiritual resounding glory.

> The northern lights bring silence. The northern lights lower the eyelids.

The northern lights waft in you and surge over you, For a world sinks gloriously down to you.

The northern lights, the son of two sun-born suns (For slumber and consciousness have created them.)

They set, in brightness, sun, moon and stars upon the throne.

So, in you, the northern lights will snatch away the night.

They see the suns, reveal the suns, generate the suns.

The northern lights rise up where the shafts of consciousness gape open.

The northern lights look upon you, entangled they glow within you.

You love them graciously, they will be comforted in you:

You sleep. If you forget yourself, then the glow has won:

And soon the day will dawn, innocent and pure.

Figure 4. Theodor Ddubler in Greece, 1923.

In the section `Flaming Stream of Lava,' there are a number of poems containing auroral themes, including `Northern Shimmer.' The remaining poems of Das Nordlicht which directly concern this subject are given in full in the German edition of this book. In an essay published posthumously, Daubler gathers together the basic elements of his epic, and fits them together in a cosmic and Christian world conception.

> The Son of Man is the sun in the Spirit. He guides us to his vineyard which needs our care. The ancient brotherhood of all creatures is

> disclosed to the One who is well-disposed. Simplified, we shall find ourselves again. Unnamed rays from the earth, unseen from the stars, will watch over and transform the circumstances of the living. But our death is coming. We are our own stranglers. However, the Lord is with the living. Where the earth grows inert, the northern brightness pervades the night. There, a comet breaks in from seeds in order to swirl through the darkness. The northern lights are a mark of the Pentecostal flame. To the heads of peoples it means, propitiation in the cold light, of which it is said it is the original source before the inflamed creation. The northern lights promise: The earth will one day out of itself become a radiant star. The northern lights proclaim: The speck of dust, earth, will become the spark of freedom in the universe. This wish, coming from the dark star, will never be realised in the spirit. The creation was made to this end, to this end was man born. The Son of Man will remain among us so that the Spirit may come to rule. Quivering northern light above the mountains of ice, indicate that the Pentecostal flames fade into the dusk through the peoples. If enlightenment comes to a human being then in tongues a peony will become visible in the polar night to the walker over the glaciers. The inner sun dawns as inner brightness: Northern brightness gives rise to reverence in the creature, unites us in peace, promotes freedom in humanity.12

In this future, human beings will find themselves again, and will remain, in the spirit; the aurora unites people with the spirit. This is reflected in the last of Theodor Daubler's poems in Das Nordlicht.

> The veil of fire that mildly runs through us, Has no more thunder-words in its lap, Each sound springs forth as an ordering member.
>
> The earth burns. Invulnerable to the red thrust Out of the underworld, whence the auroral gold exudes, Its favourite son attains eternal greatness!
>
> O flames that give eternal life to us, Denying the body, I can quaff the soul, You are the spark that loves the stars.

While taking form the auroral arcs proceed from east to west. The lower edges of the arcs are sharply outlined; the upper edges dissolve away. When the arcs move stronger colours appear. In this way the arcs can move futher towards the zenith.

You still fly about the pole in centrifugal fling, From the earth's heart

into space above, But remain in us who need the fire!

Once, heaven's gates will burn in me. Auroral lights will disappear from the firmament For each being is a fiery meteor.

Then we will find the other world within us, Where no one emerges from the spirit-ocean, Aurora borealis can unite us with the spirit.

3. The Northern Lights in History

Ancient Greece and Rome

The first certain and exact description of the northern lights appeared in the West in 467 BC. Plutarch (C.AD 46-125), Greek philosopher and writer, says in his treatise on Lysander:

> ... for seventy-five days continuously there was seen in the heavens a fiery body of great extent, like a flaming cloud that did not rest in one place but moved along with intricate and regular movements so that through its darting and unsteady progress fiery fragments were broken off, and fiery flames were borne in all directions just like shooting stars.'

It was only in the centuries preceding Plutarch that external perception and inner vision began to separate. As a result humanity's first scientific age began which was conceived and established by Aristotle (384-322 BC). Among many other things, he also observed the northern lights scientifically. Although they are extremely rare in Mediterranean countries, he had most probably seen the intensive outburst of northern lights in Greece in the years 349 and 344 BC. He gives a brief description in his work, Meterologica: `On a clear night a number of phenomena can be seen that take on the forms of chasms (chasmata) trenches and blood-red colours.'2 In line with his conception of the basic four elements, earth, water, air and fire, on which the structure of the world is founded, Aristotle describes how a vapour caused by the sun rises from the earth and collides with the sun's fire at the altitude of the sub-lunar sphere where it is ignited and thus produces the coloured flashes of the northern lights. Understood in an imaginative pictorial manner, it is astonishing how exactly Aristotle discerned parts of the basic auroral process.

In Rome, Seneca (c.4 BC - c.AD 65) also described the northern lights. This writer, historian and statesman had a surprisingly precise knowledge of auroral corona. In his work Naturales Questiones he describes this phenomenon:

Many kinds of them are seen. There are bothnyi [abysses]: within a surrounding corona there is a great gap in the sky like a hole dug in a circle. There are pithiai [casks]: an enormous round mass of fire, like a barrel. either darts by or blazes in one place. There are chasmata [chasms]: some area of the sky settles and, gaping in hiding so to speak - sends out flame.-

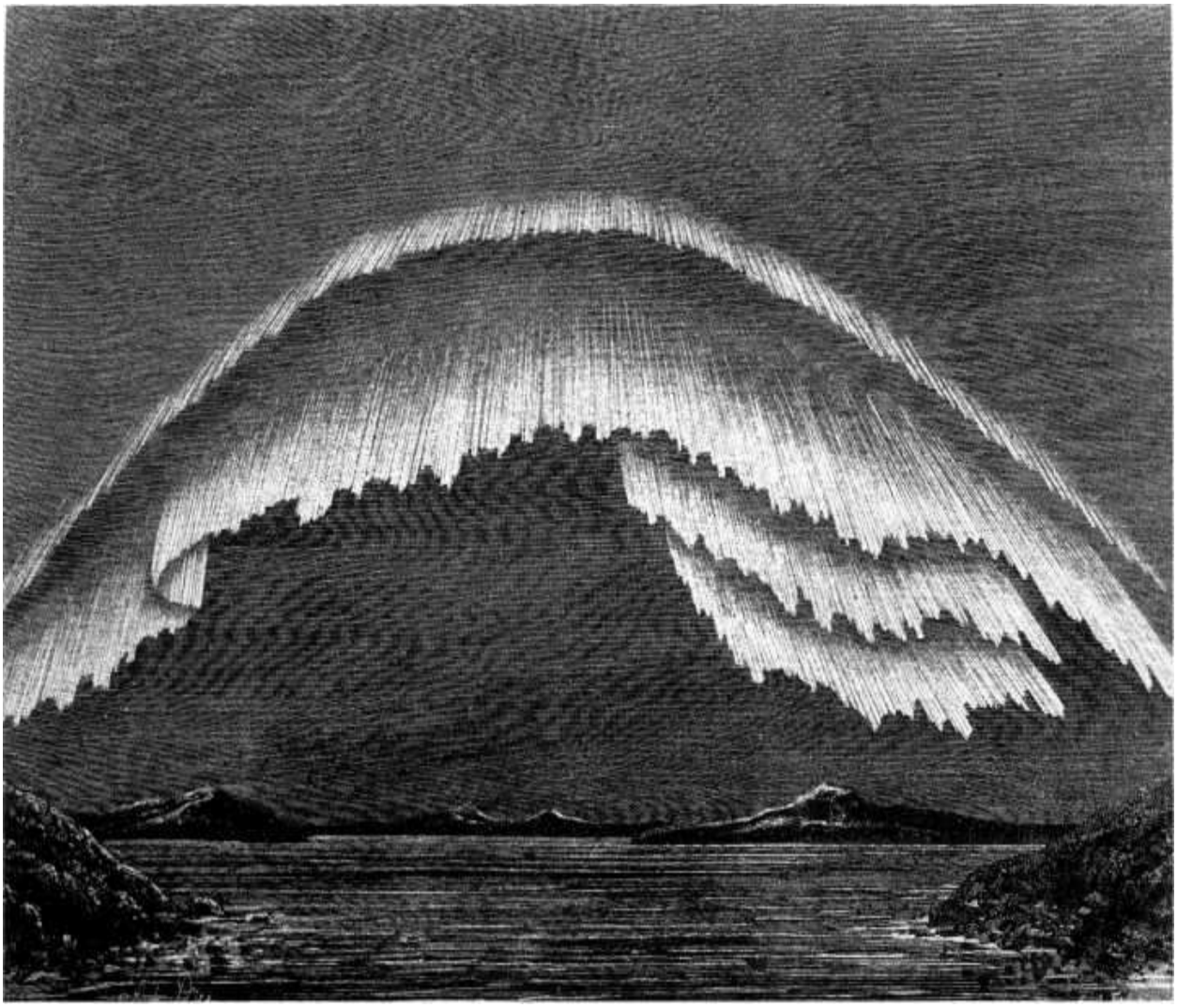


Figure 5. The following three engravings were from drawings made during the French Arctic expedition to Bossekop (now Alta) Finnmark, Norway in 1838-40. Here an arc changes into bands.

In the Mediterranean countries the northern lights appeared mostly on the horizon and were, therefore, coloured red by dust and clouds. These fire images also became a characteristic symbol of the burning demise of the

Roman world. Contemporary accounts, for instance, those by Pliny the Elder (AD 23-79), are also the last precise descriptions for about one thousand years, during which people's relationships with unusual natural phenomena were almost solely governed by fear and superstition. This condition remained into the age of the Renaissance, together with a mysterious belief in miracles.

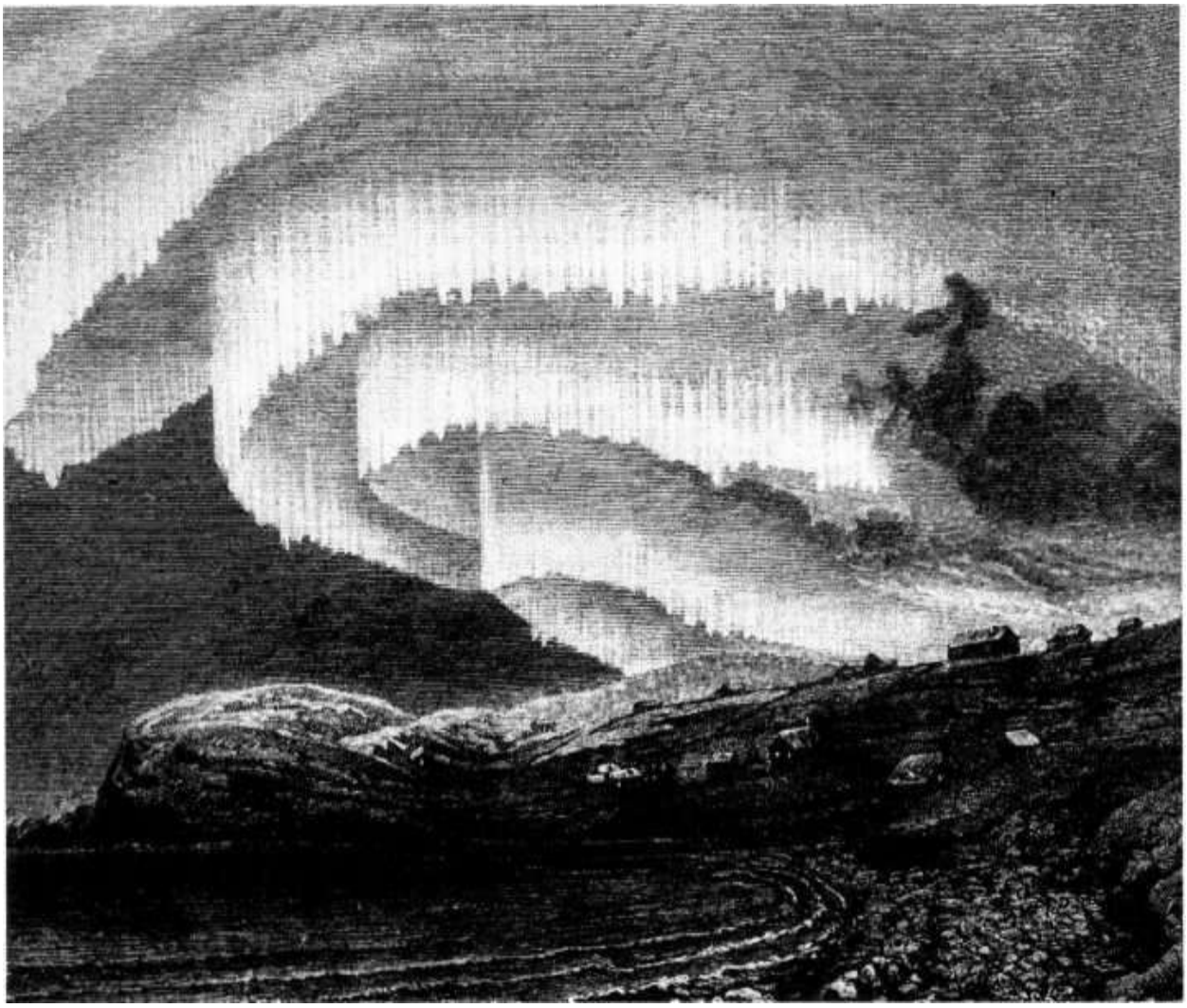


Figure 6. A set of pleated draperies. (French Arctic expedition 1838-40).

The Edda and King's Mirror sagas

In the early Middle Ages human beings still looked into the supersensory realm of myth in a dream-like, clairvoyant manner. The Edda in Iceland was a result of this perception, leading to the Norse history of gods and men.

Hearing these myths one becomes aware of an inability to differentiate between the external world of perception and the inner world of the imagination.

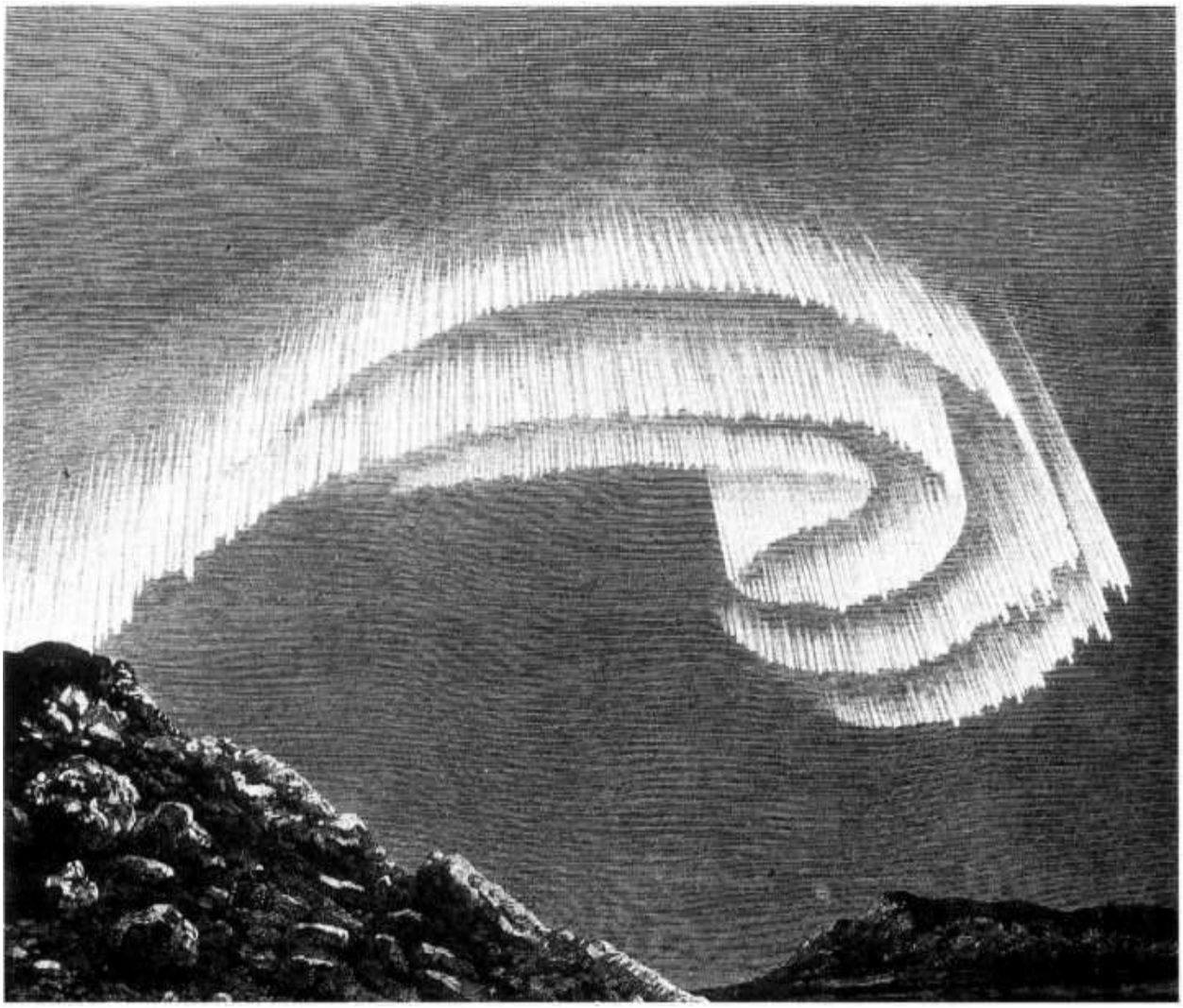


Figure 7. Curtain-like draperies fold into spirals (French Arctic expedition 1838-40).

Nowhere in the Edda, despite its north European origin, can one find with certainty a description or mention of the northern lights, although many light and colour phenomena are referred to. This fact can be attributed partly to a supposed decrease in the activity of the northern lights during the centuries of the Elder Edda's composition (eleventh century and earlier). In the Norwegian saga, The King's Mirror there is a section which, until a few years ago, was regarded as quite puzzling. This work originated in the thirteenth

century, and tells how a man from Trondheim in Norway, passes his wide-ranging knowledge and experience of the then-known world on to his son. In connection with descriptions of Greenland, the son enquires about the northern lights. The father answers:

> But as to that matter which you have often inquired about, what those lights can be which the Greenlanders call the northern lights, I have no clear knowledge. I have often met men who have spent a long time in Greenland, but they do not seem to know definitely what those lights are. However, it is true of that subject as of many others of which we have no sure knowledge, that thoughtful men will form opinions and conjectures about it and will make such guesses as seem reasonable and likely to be true. But these northern lights have this peculiar nature, that the darker the night is, the brighter they seem; and they always appear at night but never by day - most frequently in the densest darkness and rarely by moonlight. In appearance they resemble a vast flame of fire viewed from a great distance. It also looks as if sharp points were shot from this flame up into the sky; these are of uneven height and in constant motion, now one, now another darting highest; and the light appears to blaze like a living flame. While these rays are at their highest and brightest, they give forth so much light that people out of doors can easily find their way about and can even go hunting, if need be. Where people sit in houses that have windows, it is so light inside that all within the room can see each other's faces. The light is very changeable. Sometimes it appears to grow dim, as if a black smoke or a dark fog were blown up among the rays; and then it looks very much as if the light were overcome by this smoke and about to be quenched. But as soon as the smoke begins to grow thinner, the light begins to brighten again; and it happens at times that people think they see large sparks shooting out of it as from glowing iron which has just been taken from the forge. But as night declines and day approaches, the light begins to fade; and when daylight appears, it seems to vanish entirely.

After the initial white colour phase the arcs often displays shades of yellow and green. The green is the basic colour of the aurora; the white of the aurora appears repeatedly and resembles moonlight.

Swinging movements in the arcs are characteristic of the dynamics and movement of the aurora. Thus a band can disappear and another emerge elsewhere. Parts of the band can also fall away or appear in other places in the sky. The green band shown here is typical of a 'normal' appearance of the aurora.

> The men who have thought about and discussed these lights have guessed at three sources, one of which, it seems, ought to be the true one. Some hold that fire circles about the ocean and all the bodies of water that stream about on the outer sides of the globe; and since Greenland lies on the outermost edge of the Earth to the north, they think it possible that these lights shine forth from the fires that encircle the outer ocean. Others have suggested that during the hours of night:, when the sun's course is beneath the Earth, an occasional gleam of its light may shoot up into the sky; for they insist that Greenland lies so far out on the Earth's edge that the curved surface which shuts out the sunlight must be less prominent there. But there are still others who believe (and it seems to me not unlikely) that the frost and the glaciers have become so powerful there that they are able to radiate forth these flames. I know nothing further that has been conjectured on this subject, only these three theories that I have presented; as to their correctness I do not decide, though the last mentioned looks quite plausible to me.4

It is evident from the son's questions and the father's answers that neither of them was acquainted with the northern lights at first hand. This is even more astonishing since it is known that around this time intensive sunspot activity must have given rise to a widespread aurora. It cannot, therefore, have been seen in Trondheim or its wider surroundings, from where, in later years, it was often visible. The mystery began to resolve itself when it was discovered that the centre of the northern lights shifted slowly in relation to the North Pole. Today it is assumed that in about 700 BC this centre lay to the north of Spitsbergen, and in about AD 1200 was near the New Siberian Islands. Owing to this displacement of the magnetic pole the whole of Norway lay considerably south of the oval of the northern lights in 1200, and was probably outside the northern lights' zone. This signifies a geographical extension of the already far-reaching dynamics of the aurora.

The Renaissance

The northern lights are barely dealt with in the great work of the Danish astronomer, Tycho Brahe (1546-1601). He only left a few obscure notes, despite being an intensive observer of the night sky. The reason for this is that during his lifetime very little of the northern lights could be seen.

However, in demonstrating that comets moved in their orbits beyond the moon's sphere, he corrected a widespread fallacy which went back to the Roman author Pliny the Elder. Pliny regarded the comets as meteorological phenomena within the earth's atmosphere. As a result of Tycho's accurate observation the space perceivable beyond the earth was extended, and this was where the aurora's development and appearance could be seen.

Figure 8. The, following two illustrations show the aurora australis in Antarctica, portrayed during the British Antartic expedition of 1901-1904. The typical arc is seen here with a few bands above.

On November 17, 1607, intensive northern lights developed over the whole of Europe. They were seen by Johannes Kepler (1571-1630), and accurately described by him. Galileo Galilei (1564-1642), witnessed a great outburst of the aurora in Venice in 1621. These two give the first factual accounts of the northern lights in Central Europe. Aurora borealis, the name used internationally today, springs from Galileo. It appears for the first time in an essay that he published in 1616 together with his pupil, Guiducci. In it,

as well as comets, he deals with the northern lights and, describing the astonishing illumination in the northern sky, he concludes with the words: `... thus forming for us this northern dawn (questa boreale aurora).' In 1619, Galileo described the northern lights and offered an explanation which, in part, conforms to Aristotle:

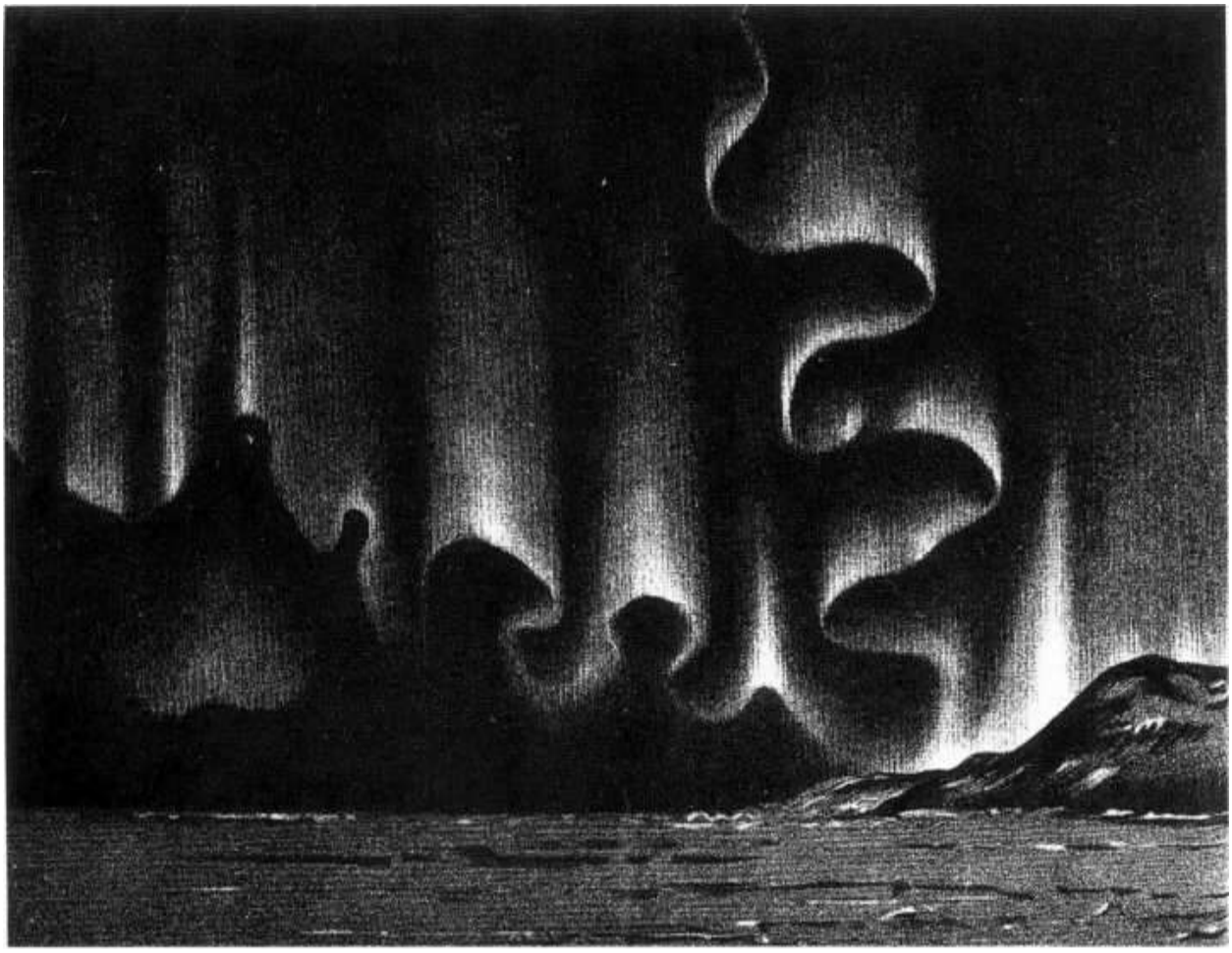


Figure 9. Curtains of aurora australis (British Antarctic expedition 1901-4).

> ... an effect: which in my opinion has no other origin than that a part of the vapour-laden air surrounding the earth is for some reason unusually rarefied and extraordinarily sublimated has risen above the cone of the earth's shadow so that its upper parts are struck by the sun and made able to reflect its splendour to us, thus forming for us the northern dawn.5

Rene Descartes (1596-1650), the French philosopher, wrote the work Meteora in which he also discusses the northern lights but his accounts do not

infer that he had ever seen this phenomenon. His conceptions were therefore highly speculative. He supposed that a quantity of `wind-clouds' would collide, put the air under pressure, and excite it, so that - similar to the then prevailing conception of the cause of lightning - light would be generated. Some of his other ideas were: there is a powerful terrestrial flame that is reflected from the clouds; seeing the aurora as sunlight reflecting on ice crystals at a great altitude. The latter kept reasserting itself throughout the centuries. Around this time, and for almost one hundred years, there were few appearances of the northern lights. Between about 1620 and 1725 there was a period known today as the Maunder minimum.*

Magnetic theories

The second half of the Maunder minimum coincided with the first half of the life of Edmund Halley (1656-1742), the great English astronomer after whom Halley's Comet was named. He said that he was dying to see the aurora but expected to die without seeing it.

In 1716, Halley was blessed with the opportunity to witness the finest aurora in a century. For the Royal Society he wrote a treatise postulating a force of subtle nature, and called it Magnetical Effluvia, a magnetic exhalation, capable of penetrating all substances, including gold. Halley thus delineated the earth's magnetic field. The descriptions appertaining to it are linguistically aphoristic but enter with astonishing insight into the present state of research:

> ... which subtile Matter freely pervading the Pores of the Earth, and entering into it near its Southern Pole, may pass out again into the ether, at the same Distance from the Northern, and with a like force; ... this subtile Matter, no otherways discovering itself but by its Effects on the Magnetic Needle, wholly imperceptible and at other times invisible, may now and then, by the Concourse of Several Causes very rarely coincident, and to us as yet unknown, be capable of producing a small Degree of Light; ... I assume the Effluvia of the Magnetical Matter for this purpose, which in certain Cases may themselves become luminous, or rather may sometimes carry with them out of the Bowels of the Earth [to be] a sort of Atoms proper to produce Light in the Ether.6

Nevertheless, despite these far-reaching insights, Halley could not yet discern the relationship of the aurora to the field lines of the magnetic field surrounding the earth.

It was only a year before Halley's death, in 1741, that researchers in Scandinavia established the close connection between the magnetic field and the northern lights. The Swedish astronomer, Anders Celsius (1701-44) and his brother-in-law, Olof P. Hiorter, (1696-1750) directed their attention to the deviation of the compass needle in the presence of magnetic disturbances and the simultaneous appearance of the aurora. In 1733, Celsius, known for his grading of the thermometer, published a comprehensive treatise on the northern lights which attracted attention throughout Europe. Celsius left a magnetic needle in Uppsala, which Hiorter monitored day and night, noting his observations almost every hour. From 1741 to 1742 he took 6,638 readings (a year has 8,760 hours!).

From this, the close relationship between the aurora and movements in the magnetic held became evident. The full incorporation of the aurora into the magnetic field was, however, first undertaken by the Swedish physicist Johann C. Wilcke (1732-96). He became known through his publication of maps of the world inscribed with magnetic field lines and the corresponding inclinations (vertical magnetic inclinations). The sight-line into the aurora's corona lay parallel to the geomagnetic field lines, and the compass needle pointed in the same direction.

Luminosity and electricity

The progress in experimental physics in the eighteenth century proved advantageous to the Danish bishop in Trondheim, Erich Pontoppidan (1698-1764) who came to the conclusion that the aurora was an electrical phenomenon. A friend had drawn his attention to a paper by a Frenchman, M. Desaguliers, who described how heavy raindrops could be held suspended in lighter air by electric forces. This led Pontoppidan to his idea:

> One can imagine the earth's globe with its encircling air as a glass globe in an electrostatic machine. When the air is pumped out and the globe rapidly rotated then a purple coloured flame, which is also the colour of the aurora, sinks down within it; this flame must be the ignited ether

> (aether ignens) ... The northern light observed in the direction of the pole will not only have its origin in the ether but will itself be ether ...

Electrical and old ether conceptions here form a peculiar association. The most exact observation Pontoppidan made was that the aurora did not increase towards the north but towards the north-west. From then on, attention began to be focused on the magnetic pole. Halley had already indicated a method for the exact measurement of the aurora's altitude: triangulation. Two people make observations of the aurora from two different positions, far enough apart to enable them to get clear angular measurements. From the results of these measurements the height of the aurora can be estimated. The difficulty with the aurora is that the observers must ascertain that they are monitoring the same point on a stationary curtain of the aurora. This proved to be very difficult. It was the English scientist, Henry Cavendish (1731-1810) who first succeeded in using this method successfully. In 1796 he came to the astonishingly exact result of 52 to 71 miles (83 to 114 km). This method, however, could be only verified in the twentieth century by modern communication. Until modern time there was great uncertainty regarding the altitude of the aurora, for the results oscillated between ground level and over 1000 kilometres (600 miles). As Cavendish's results could not be verified they were not generally recognized.

In the north, the winter is not as dark as is generally supposed because the snow reflects the light from the moon and stars. In addition there is an even stronger light from the aurora which at certain times appears every night in the far north. The snow reflects not only light from the aurora but also its whole spectrum of colours, giving colours to the landscape which are

comparable to those brought forth by the sun in the south.

At first, the aurora often displays a white arc, similar to a rainbow but much larger. Movements arise and colours emege through them, together with manifold swings and convolutions. As in this picture, the outcome may be a waving band similar to a veil, and often resembling a curtain.

Russian research

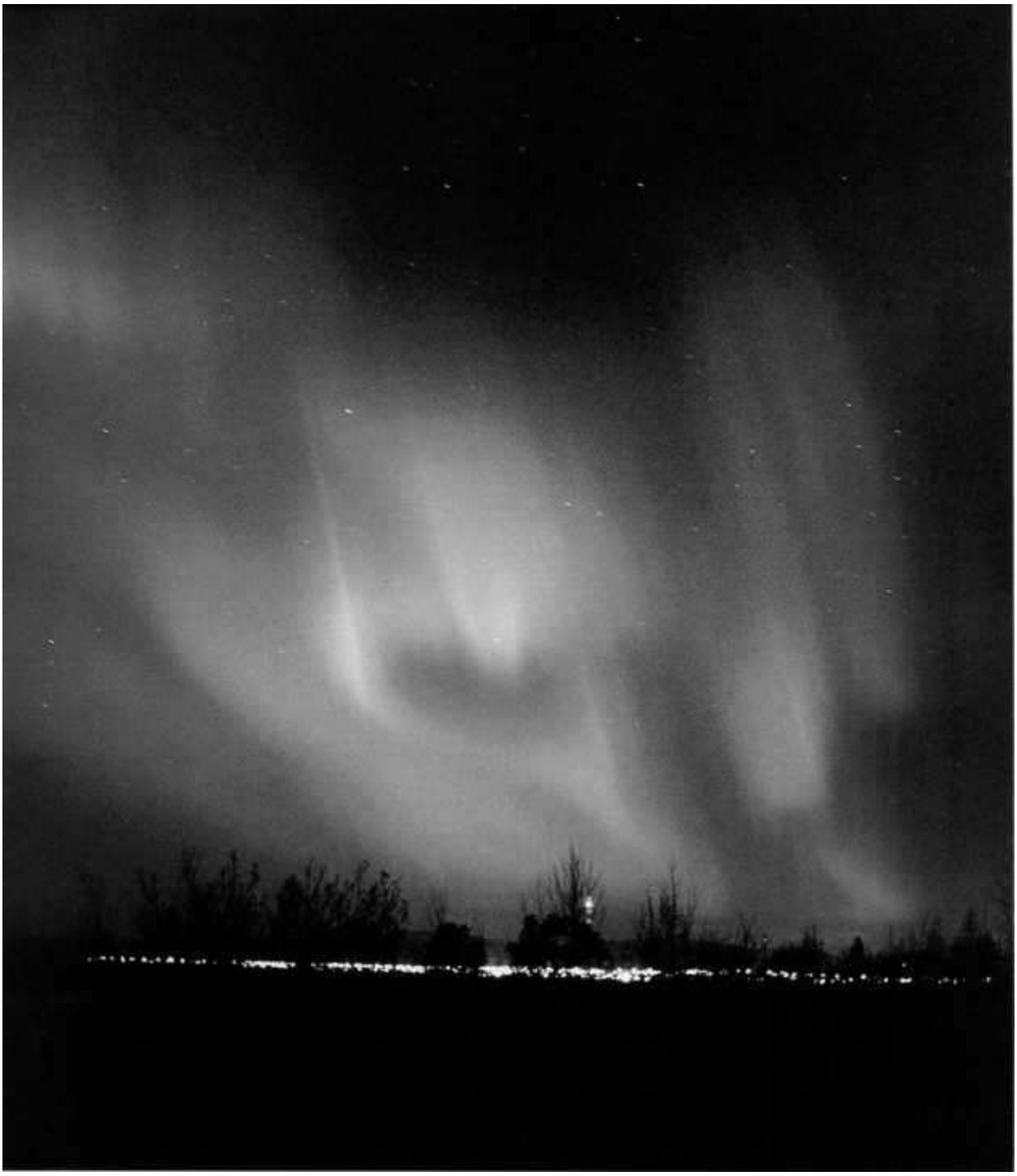
In northern Russia, the aurora was a frequent phenomenon. Descriptions go back to the year 919, and the mysterious light played a decisive role in wars and battles. Later, in 1792, on the Caspian Sea near Astrachan, Peter the Great (1672-1725) saw the aurora which he described as a great fire. This outburst of the aurora, visible as far south as latitude 46° N was observed on the same night in Paris, Berlin and Lynn, Massachusetts (42° N).

Towards the end of his life the great founder of Russian science, linguistics and literature, Mikhail Lomonosov (1711-65), intended writing a comprehensive work on the northern lights in three parts. When a boy, at his home in Kholmogory not far from the White Sea port of Archangel (65° N), Lomonosov frequently lay on the ground looking up at the northern lights, dreaming his way into the colourful fluctuations of its forms. People often had to wake him from his trance-like state. He was the son of a poor fisherman, but through great effort and sacrifice managed to study in Moscow, going on to become a universal scientist. Following the electrical theories of Benjamin Franklin (1706 -90), Lomonosov conducted many experiments to prove the luminescent electrical nature of the northern lights. Connected with this was his conception of rising and sinking air streams in the region of the pole. According to his view, these generated tensions of friction which then discharged themselves in the aurora and became luminous. In 1763, during the preparation of an expedition to find the north-east passage to Siberia, Lomonosov vigorously postulated that there must be a great expanse of unfrozen water in the polar region from which these hypothetical warm air streams rose.

His intended great work on the aurora borealis was only begun; some chapters are preserved as well as the draft for: firstly, research into the origin of the aurora borealis; secondly, theory of electrical forces; thirdly, appearances of the aurora borealis. Forty-eight drawings by Lomonosov himself were to illustrate the work. A number of these drawings still exist and may be found in the complete edition of his works. In his book, Rhetoric, Lomonosov has a poem:

But where, oh Nature, is thy law?
From midnight lands the morning dawn emerges!
Does not the sun take up his throne?
Do not frozen seas ray forth his fire?
Behold, a cold flame has enclosed us!
Behold, in the night, came day to earth.

The end of the eighteenth century saw a profusion of theories and contradictory observations along the road to an understanding of the aurora which were only ordered and consolidated in the course of the nineteenth century.



The expansion dynamic of the aurora is astounding. Large parts of the sky can be quickly covered with veils of colour. In rare cases the whole dome of the sky is filled with auroral colours. In this picture the electric lights in the town of Kiruna give an impression of the energy involved in an auroral display, which far surpasses the energy produced on earth.

4. Science and the Aurora

Around the beginning of the nineteenth century, scientific research was increasingly concentrated upon the aurora's magnetic and electric nature. Christopher Hansteen (1784-1873) occupied the chair for mathematics and astronomy in 1812 at the University of Christiana (Oslo) following his exposition of an award's question: `Can all the earth's magnetic phenomena be derived from a magnetic axis, or must more be presupposed?' In 1829-30 Hansteen undertook an expedition to Siberia to investigate the unusually strong geomagnetic field there. He observed how, prior to an outburst of the aurora, the magnetic field's horizontal components increased, only to decrease after the lights' display. He could also show that the highest point of an auroral arc usually lay in the neighbourhood of the observer's magnetic meridian.

The result of this research demonstrated conclusively that the aurora was related to magnetic phenomena. Already during his student days, Hansteen's interest in the significance of the earth's magnetism had been encouraged by the Danish physicist, Hans C. Q rsted (17771851). He too investigated the aurora and in 1826 referred to the fluctuating magnetic field surrounding the aurora's arcs, which could result from electrical discharges along the arcs. frsted's discoveries were not fully explained for another hundred years, when the outer atmosphere, the ionosphere was found to be an excellent conductor of electric current.

In 1827, the French physicist Jean B. Biot (1774-1862), stayed on the Shetland Islands, Scotland, to observe the northern lights with a polarimeter, an apparatus used to study optically active substances. He found no trace of polarization, establishing beyond doubt that the aurora could not be a reflection of the sunlight, which was still a widely held belief.

Spectral analysis

During these years, the use of spectral analysis was developed. When light shines through a prism it is split into a coloured band, a spectrum. The spectrum can be calibrated to the wavelengths of the different colours, and

careful observation shows bands of dark lines and bright colours. These are related to certain substances in the light source; the pattern, or spectrogram,, establishes the presence of certain gases in the object. Sunlight, when photographed, shows a consistently complete colour spectrum. The Swedish physicist, Anders Jonas Angstrom (1814-74) examined the aurora with a spectrometer and ascertained that it consisted of luminous gases and not, as hitherto had been thought, other substances such as water or ice particles. The dominant colour line of the spectrogram, measured by Angstrom, was yellowgreen. He used a unit of measure that was later named after him; its value was one ten millionth of a millimetre. Angstrom's measurement of the yellow-green aurora gave it 5567 units of length. The exact measurement was later determined to be 5577 A (angstrom).

Sunspots

In the first days of September 1859, there was the most spectacular display of the aurora ever seen. In Puerto Rico (latitude 18° N) the aurora was observed in the zenith. Had there been observers to watch it, it could probably have been seen over the whole earth. Prior to this display, an English astronomer had observed extremely bright radiating eruptions on the sun. Richard C. Carrington (1826-75) who had first studied theology, owned a private observatory in Redhill, England, and was particularly interested in sunspots. On 1 September, 1859, Carrington was drawing sunspot groupings projected by the telescope. He describes his experience:

> ... when within the area of the great north group ... two patches of intensely bright and white light broke out ... My first impression was that by some chance a ray of light had penetrated a hole in the screen attached to the object glass, for the brilliancy was fully equal to that of direct sunlight, but ... I was an unprepared witness to a very different affair. I thereupon noted down the time by the chronometer, and, seeing the outburst to be very rapidly on the increase, and being somewhat flurried by the surprise, I hastily ran to call someone to witness the exhibition with me, and on returning within 60 seconds, was mortified to find that it was already much changed and enfeebled.'

Eighteen hours later, the most powerful magnetic storm ever recorded swept over the earth, causing a world-wide visible aurora. The relationship

between solar flares connected with sunspots and the aurora was, for Carrington, emphatically established. However, he withheld his conclusions in order to find more definite confirmation.

Sophus Tromholt

Since the middle of the century the attention of researchers had been directed towards connecting solar activity with the aurora. Finally the Danish pedagogue and physicist, Sophus Tromholt (1852-96) established the link. As a teacher, he was transferred from Denmark to Norway and soon received state stipends which made it possible for him to devote all his energy to auroral research. Tromholt stayed in Norway for twenty-five years, and during this time he set up an expansive network of observatories in more than a hundred Scandinavian locations, from which he received findings. In addition, several thousand individuals contributed to the completion of the observations.

During the first International Polar Year (1882/3) he was responsible for one of the two Norwegian observatories in Lapland (Kau- tokeino). Here in the north, Tromholt began to interest himself intensively in the life of the Lapps; photographs show him in Lapp costume together with his observatory equipment. His experiences during this sojourn in the far North are described in his book, Under the Rays of the Northern Lights. This work, translated into many languages, deals primarily with the culture of the Lapps, and the chapter on the aurora is professional and comprehensive. Based on the information received and on his own experiences, Tromholt formed an exact picture of the auroral oval in its planetary dimensions, but his work was largely overlooked by auroral researchers because his book did not appear as a scientific publication:

> On account of the great circumference of the earth, in proportion to the height of the aurora, only a small portion of such a ring would be visible at one time, and each observer only see his own portion, the situation of which in relation to his horizon and the Zenith will depend on his position in relation to the auroral ring.2

This ring - the oval pulsates, spreads out dynamically towards the equator, while its low light centre also expands and contracts again with the sun's

activity, known as the sunspot rhythm Added to this is the continually changing relationship between the oval and the rotating earth below it. Tromholt's main achievement was to have grasped this relationship through observation. The aurora was first recognized as a planetary-cosmic formation, that is, more than just a local appearance. About a hundred years later, the auroral oval could be photographed from space.

In 1881 Sophus Tromholt summed up his observations in a paper. He noticed that in the auroral zone in northern Norway there was a regular recurrence of displays, and that, for example, the further north he went, the later in the night the auroral maximum occurred. He was the first to observe, in about 1879, how the auroral oval spread towards the Equator with an increase in solar activity during the eleven-year sunspot cycles. Tromholt's far-reaching discoveries were not accepted, and his enthusiastic and large-scale work was, until recently, overlooked and unacknowledged.

It is only in the present day that his significance in the field of auroral research has been acknowledged. Even in the 1880s Tromholt wrote the following humble and enthusiastic words:

> Will man ever decipher the characters which the Aurora Borealis draws in fire on the dark sky? Will his eye ever penetrate the mysteries of Creation which hidden behind this dazzling drapery of colour and light? Who will venture to answer! Only the Future knows the reply.3

An unlimited wealth of colours is characteristic of the aurora. If in addition, the aurora is below the horizon - as in this picture - one can witness shades of colour caused by denser layers of air or light cloud.

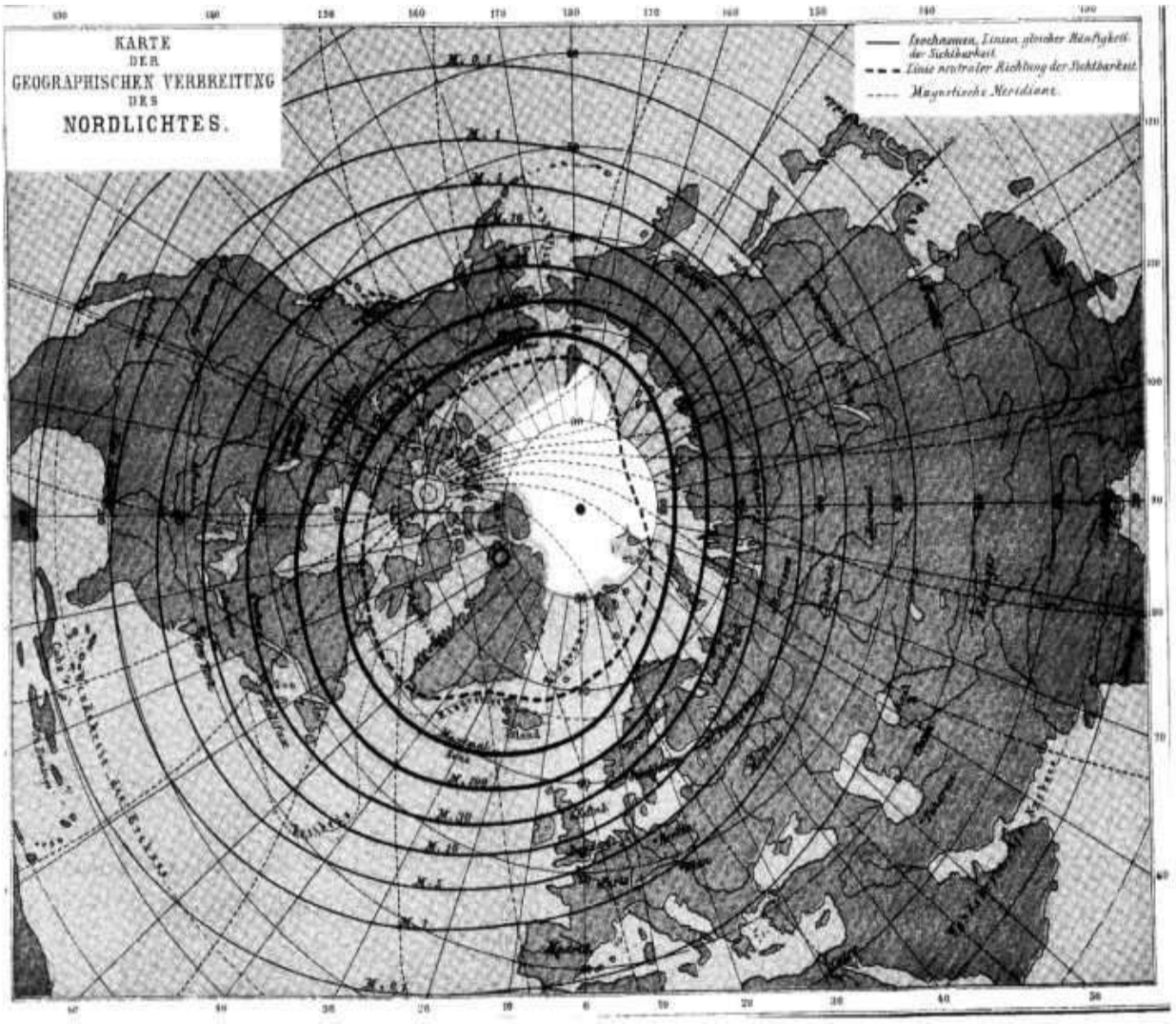


Figure 10. A map drawn by Hermann Fritz in 1881, with isometric lines, called isochasms, marking the places where the aurora is seen with equal frequency. The centre of this auroral zone is near the geomagnetic North Pole of the earth in north-west Greenland, 800 km (500 miles) north-east of the magnetic North Pole near Bathurst Island.

With this discovery in about 1879, a scientific development began which led to the present-day conception of the aurora, based on quantitative information regarding the auroral phenomenon.

The oval of the aurora

In Europe, the northern lights are most often visible from latitude 60° (Oslo-Helsinki-St Petersburg). This latitude forms a kind of light-dark frontier. At

this latitude the `white nights' begin, and in summer it remains light almost throughout the night. Several hundred miles to the north, this frontier is clearly crossed; here, at the height of summer it is completely light throughout night. In this zone, the northern lights appear frequently in the dark season of the year, and are clearly visible. Here, immediately north of latitude 60°, both light frontiers coincide: in the autumn, the waning sunlight is occasionally superseded by the developing northern lights. Further north, as far as Spitsbergen (80°), the aurora becomes more regular, more intensive and rich in formations. In the furthermost North, beyond latitude 80°, the situation changes.

In 1881, Herman Fritz (1830-93), a German physicist, published the first precise accounts on the frequency of the aurora in the northern hemisphere. He drew lines through equivalent auroral frequencies on a map of the world, centred on the North Pole. (Figure 10). These lines are called isochasms, from the Greek word chasmata a term already used by Aristotle for an appearance of the northern lights. The isochasms show the aurora as a huge oval, embracing, in its entirety, the geographical and magnetic North Poles. This oval, delineated by the isochasms on the earth's surface, is called the auroral zone. Towards the centre of this zone is the geomagnetic pole, which is, therefore, also the auroral pole. The smaller, auroral oval floating in the altitudes above it is forced away by the sun's light to the sunless side of the earth. Thus the centre of the oval rotates around the geomagnetic pole during its daily rotation of the earth.

The geomagnetic North Pole is currently situated in north-west Greenland at Thule (about 79° N, 70° W); it is the centre of the earth's radial magnetism, the magnetic field around the earth. However, irregularities within the earth's crust have shifted the centre of terrestrial magnetism. Consequently, the magnetic pole (compass north) is near Bathurst Island in northern Canada, 800 km (500 miles) south-west of the geomagnetic pole.

The most frequent isochasm is an oval band, 500 km (300 miles) wide, and about 2000 km (1250 miles) from the geomagnetic pole (aurora's centre). Inside the auroral oval the visible aurora decreases. In the region around the pole itself the aurora is hardly visible. Within the oval band the aurora's activity develops horizontally, but inside the oval the direction becomes

vertical, the altitude of the aurora increases, and the light becomes weaker.

The aurora has a milky-white appearance both as an initial arc as well as independent arcs and bands, which appear as flowing streaks in the sky. If behind cloud the aurora seems to be a meteorological phenomenon. The

landscape is so brightly illuminated that everything is clearly visible.

The aurora often seems to be pointing vertically down to the earth, and resembles tongues of flame. The snow on the tree in this picture has a pink reflection of a red aurora not visible in the photograph.

The zone of maximum frequency runs through northern Norway (Tromso),

northern Canada (Hudson Bay), northern Alaska and the sea and ice north of the Russian continent. In this zone, the northern lights are visible almost every night.

In regions lying further south, the frequency of the auroral phenomenon decreases rapidly. On the isochasm of Oslo, Aberdeen in Scotland, Donegal in Ireland, Newfoundland, Quebec and Lake Superior in Canada, Anchorage in Alaska, Siberia and Archangel in Russia the aurora appears on thirty to forty nights of the year, but is not frequently visible, as greater cloud formation or haze hinders visibility on many nights.

In Central Europe and the Southern United States the frequency of auroral sightings is reduced to between one and seven nights a year; the aurora is thus seldom visible. However, with careful observation it can be seen. In the Mediterranean region, in Mexico, in Hokkaido, Japan and in the regions of the Caspian and Black Seas, the aurora only appears roughly once every ten years. Nevertheless, on rare occasions, powerful auroral displays can be seen over the whole earth.

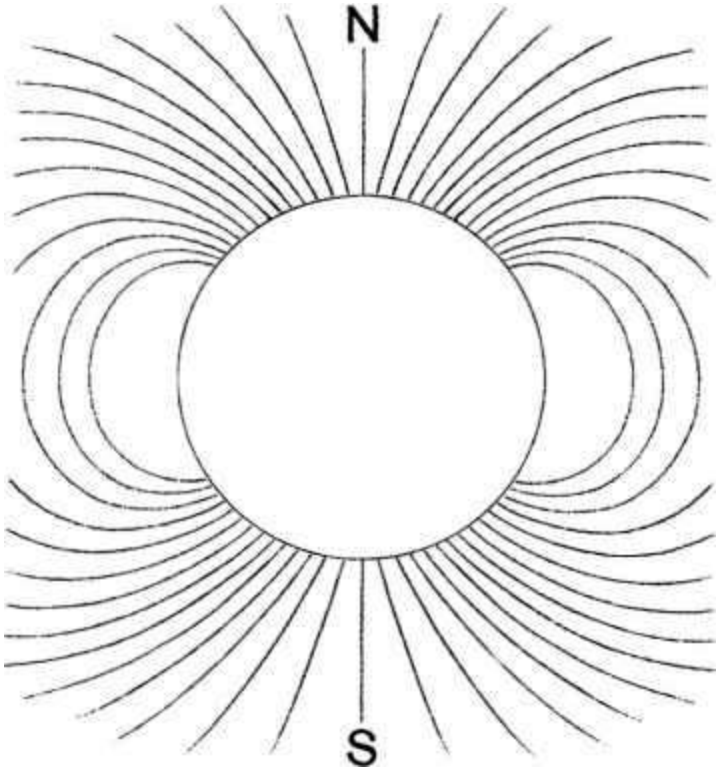


Figure 11. The magnetic field around a magnetized sphere, or the earth.

Magnetism and aurora

The close relationship of the aurora and magnetism is evident in the approximate centring of the auroral oval in the geomagnetic pole. The aurora appears along the lines of magnetic force, which encircle the earth in north-south lines like a longitudinally structured network. The lines dip towards the poles (Figure 11). This magnetic line structure around the earth is not rigid, but ever-changing, vibrating, erupting and producing powerful magnetic field variations.

The auroral display is largely hidden from everyday perception since the areas of the northern hemisphere from where it can be seen have, on average, only one inhabitant every two square kilometres (one per square mile). In the southern hemisphere, the aurora australis is visible in virtually uninhabited regions, and in Melbourne, Australia, its appears about as frequently as in Central Europe. Consequently, only a tiny fraction of the world population lives in the immediate vicinity of the visible auroral zone, where it occurs between one and seven nights a year. Viewing the aurora borealis is, therefore, exceptional in ordinary human experience.

It is only with nineteenth and twentieth century achievements in science and technology (such as observations by satellite) that a comprehensive global phenomenology is possible. This shows that auroral displays in the northern and southern hemisphere develop similarly, and are related.

The Danish scientist, Adam Paulsen (1833-1907) acquired Tromholt's results and continued work on them. The physical nature of the surface eruptions on the sun was still unknown, Paulsen assumed that these flares gave rise to ultraviolet radiation which, in turn, caused the aurora. He compared this process to cathode rays the stream of electric current in a vacuum. This concept, though incomplete, was essentially correct. Attention was thereby drawn to the cosmic stream of ions coming from the sun which, in the second half of the twentieth century could be observed in detail.

The aurora can give the effect of revelations from above, thus evoking the mood of Christmas. However, the coloured rays are broad bands, falling vertically in folds. Seen from spacecraft they appear as coloured columns of light. This radiance may suddenly disappear into darkness.

The electrical nature of aurora

The work of the Norwegian auroral researcher Kristian Birkeland (1867-1917) made a significant impact. In 1896, he presented his theory: that electrically charged particles from the sun reach the terrestrial magnetic field at almost the speed of light. Here they are conducted along the magnetic lines of force to the poles. As a result, the particles run along complex spiral paths and on meeting the earth's atmosphere they slow down and become luminous.

Birkeland soon went on to test this theory by thorough experiment. He constructed a model consisting of a sphere that contained a charged electromagnet in a vacuum chamber. The sphere represented the earth with its magnetic field, and the surrounding vacuum the empty space in the universe. The magnetized sphere was bombarded by clouds of electron particles, and luminous rings formed around both poles, producing an artificial aurora.

Birkeland calculated the path of the electron particles, and like Tromholt, set up aurora stations across Scandinavia: in northern Norway (Bossekop), Iceland, Spitsbergen and Novaya Zemlya. His observations, calculations and, above all, his imaginative conjectures led him to believe that the same particles that give rise to the aurora also cause deviations in the geomagnetic field. Birkeland described and worked out the electric forces in the outer atmosphere (ionosphere) and portrayed how, to begin with, these follow the geomagnetic lines of force and then, with decreasing altitude, are transferred to the auroral arcs. These energy storms are still called Birkeland currents. The basic difficulty in Birkeland's interpretation arose because the physical nature of the on-coming solar particles was unknown; they were considered to be similar to light, but a discrepancy emerged between the particles moving at the speed of light and the clear observation that, following a solar eruption, at least half a day passed before the aurora lit up. (Of course, when the eruption is visible from the earth, the sun's light has already reached the observer.)

Through Birkeland's efforts, the subject of geophysics was created and attracted enthusiastic students, of whom the best-known was Carl Stormer (1874-1957). Stormer was a mathematician and took over the calculating of particle trajectories from Birkeland. In 1907, he published an account of his findings which was not fully acknowledged until fifty years later in the International Geophysical Year of 1957. Stormer showed how incoming

particles approach the polar regions in ever closer spirals until they come to a stop momentarily close to the earth where they `reflect' for a time. Afterwards, the particles could immediately transfer to the other pole where the same occurrence was repeated. This explained the simultaneous appearance of the aurora at both the North and South Poles.

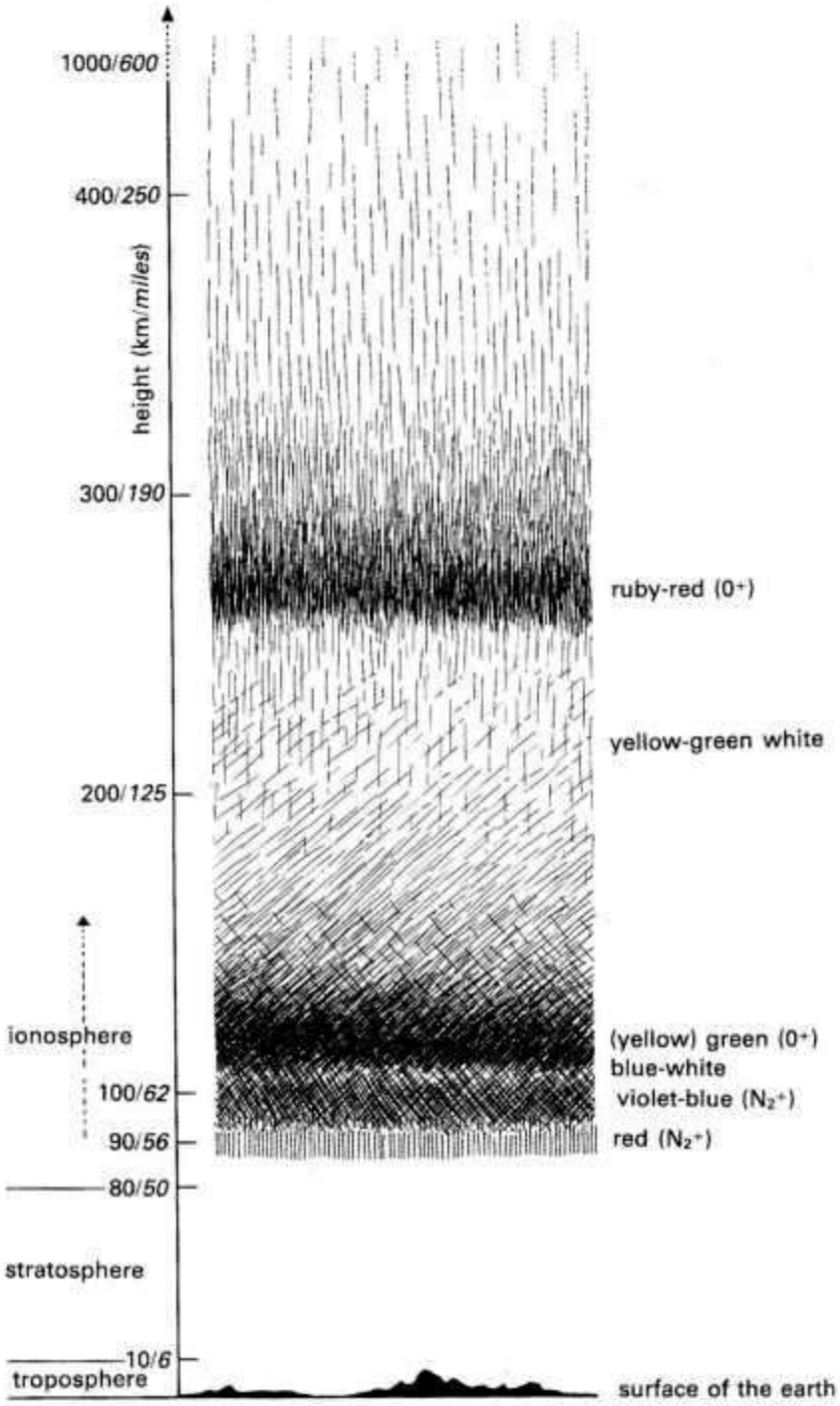


Figure 12. Distribution of the aurora in terms of height, showing its colours and the elements present. The white colour arises as a mixture of the complementary colours of the aurora.

Colour and altitude of the aurora

To ascertain the height of the aurora Stormer experimented with photography in 1909. Eventually he found a small very fast photographic lens which gave excellent results. With this and a plate sensitive to violet he succeeded in taking pictures of strong northern lights with an exposure time of one second or less.

The next step was to photograph the aurora simultaneously from two different stations connected by telephone. By observing the different positions of the aurora against the background of the stars, as seen from each station, the altitude could be calculated.

Stormer took 40,000 photographs of the aurora of which 9,000 were taken simultaneously from two separate positions. He thus found that the aurora begins at over 70 km (45 miles), reaches an altitude of 100 km (65 miles) and, in ever-diminishing intensity stretches upwards to about 900 km (550 miles). In addition, Stormer discovered that the aurora is illuminated by the sun at an altitude above 200 km (125 miles). This is faintly visible in the late twilight hours.

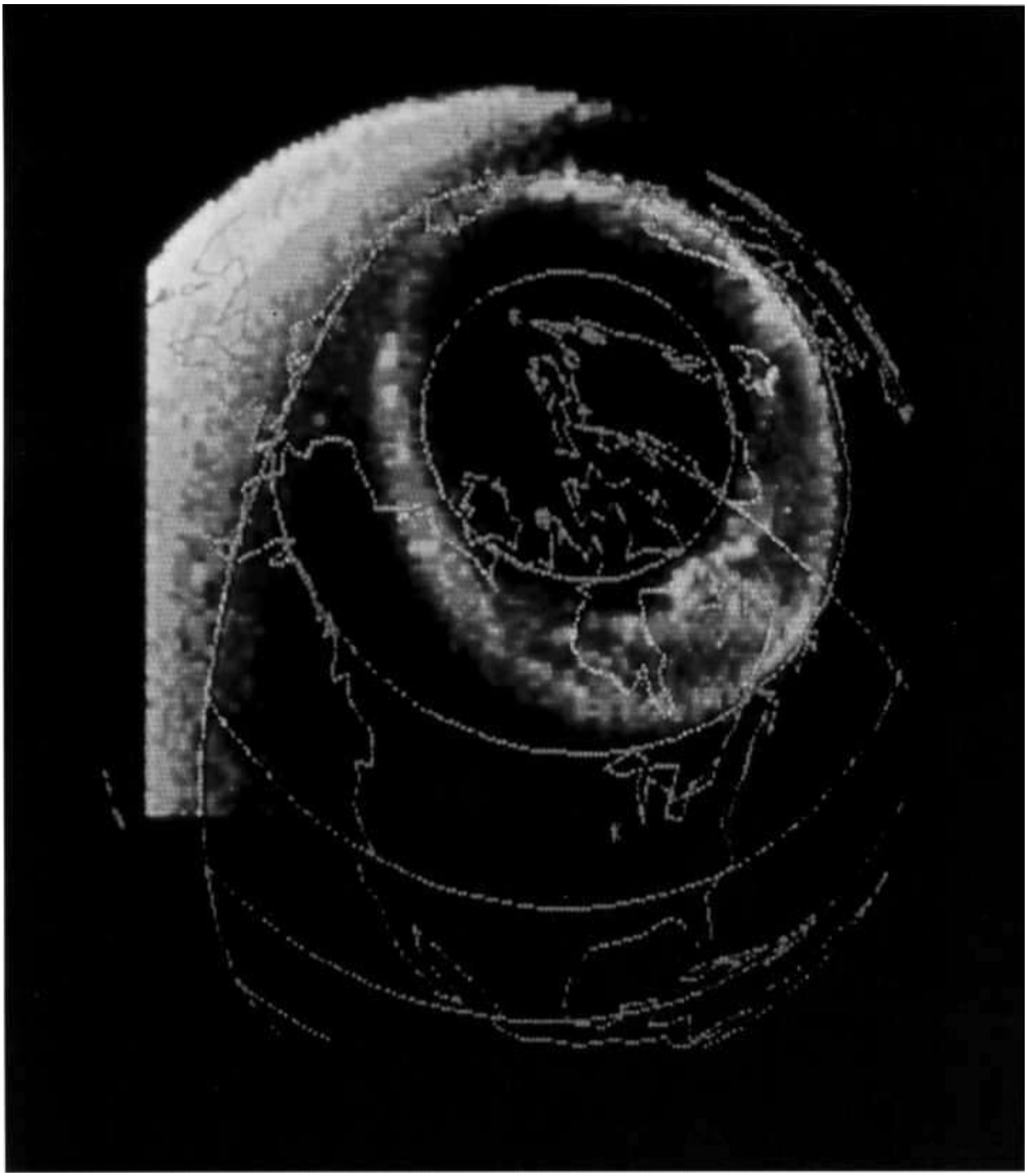
Another researcher who belonged to Birkeland's circle was Lars Vegard (1880-1963). Vegard devoted himself to the spectral analysis of the aurora, continuing the work of Angstrom. The latter had discovered the aurora's green lines, which now constituted a problem, as a gas could not be found that showed the same wavelength in spectral analysis. It was many years later (1923) that these lines were identified by showing that they were based on an emission that occurs only in rarefied matter, such as the upper atmosphere.

The aurora's light and colour are the result of an encounter between solar-related plasmic particles and gas particles in the earth's upper atmosphere. The composition of atmospheric layers was established by comparing the results of spectroscopic analysis in the aurora with the characteristics of known gases. It was ascertained that the aurora's altitude, atomic and

molecular oxygen and nitrogen are predominant. The illumination at different altitudes is occasioned by the fluctuating intensity (velocity) of the on-coming particles. Particles with the greatest velocity penetrate most deeply into the atmosphere. It has been shown that the blue-violet and red bands of the nitrogen spectrum prevail in the lowest regions of the aurora, below one hundred kilometres, (60 miles); the green oxygen line is strongest between 100 and 240 km (60-150 miles); and above 240 km (150 miles) red oxygen lines appear (see Figure 12).

Having established a relationship with terrestrial substances a connection with solar-related substances was now sought. As it was already known that helium and hydrogen emanated from the sun in ionized processes, scientists expected to also find them in the auroral spectrum. However, Vegard only discovered the hydrogen line in the spectrometer in 1939. He started with the hypothesis that, if negatively charged solar electrons caused the aurora, then they must be accompanied by positively charged nuclei, called protons or ions, to avoid being diverted. He wrote:

> In the years 1939-41, I had already succeeded in arriving at a direct proof that these ray-bundles were built up as I had presupposed [electrons and ions]. In Oslo in 1939 we took one series of auroral spectrograms in which the hydrogen spectrum [line] appeared particularly strong. This showed that at specific times the sun emitted positive ions [protons].
>
> In the following years we were able to record several spectrograms with strong hydrogen lines. With the aid of these records we could, for once, ascertain with absolute certainty that we were dealing with hydrogen lines; moreover, on some of these spectrograms the hydrogen lines took on the form of narrow bands which were very much shifted towards the shorter wavelengths ... This spread and shift in the direction of the shorter wavelengths could be caused only by the fact that the hydrogen atoms streaming from the light were in fast movement and above all in the direction of the observer, that is down to the earth.4



A picture of ultraviolet light taken from a satellite at a height of 20,300 km (12,700 miles) on November 8, 1981. The auroral oval is clearly visible against the continents, superimposed by computer. The centre of the plotted latitudes is not the geographic North Pole but the geomagnetic North Pole, near Thule in north-west Greenland, which is also the centre of the auroral oval. The oval remains opposite the direction of the sun. At the time of this

photograph, Asia was in sunlight while the broadest layer of the oval was over Labrador. The Northwest Territories were entering into the auroral oval in the evening, while Scandinavia (top right) was emerging from the oval at dawn.

Vegard's discovery was a breakthrough in auroral research. The socalled proton aurora had been discovered. Observation of the higher wave frequency - short waves - of hydrogen protons were interpreted as a result of the Doppler effect. The colour of the proton's light is red, and the faster the hydrogen carriers move towards the earth the more they shift towards the violet end of the spectrum.

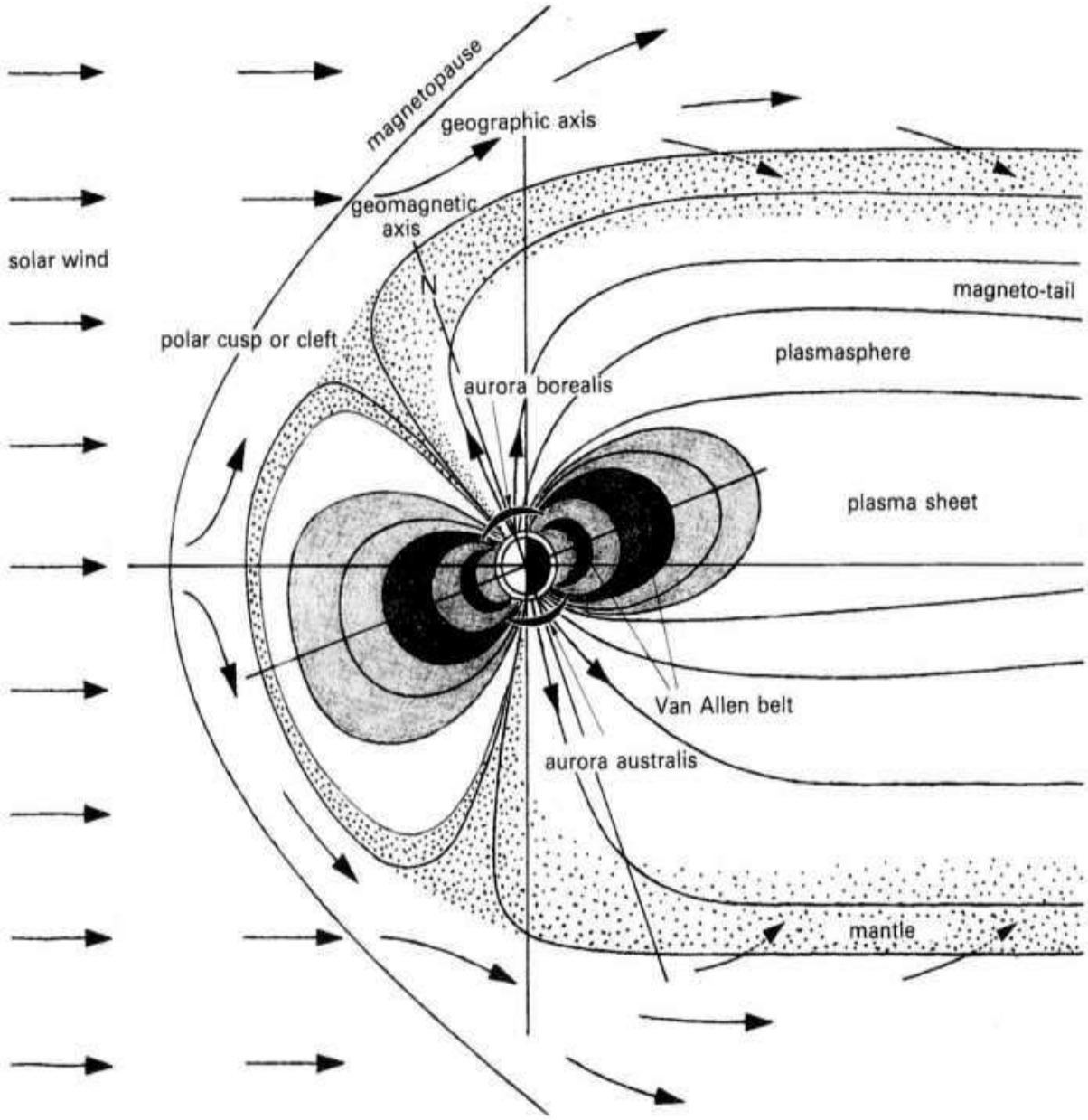


Figure 13. The magnetic structure around the earth.

Space research and the magnetic sphere

In the meantime, prior to the International Geophysical Year of 1957/58, it was known that a negative as well as a positive stream of particles triggered off the auroral display. Until now, researchers had sensed that the sun's activity was connected with the aurora, but had not been able to actually test this theory.

In October 1957, the Russian satellite Sputnik I was put into orbit round the earth, marking the beginning of the space age. This event accelerated American efforts and in January 1958 they launched Explorer which carried a Geiger counter developed by a research team led by James Van Allen. The results revealed such powerful radiation (X-rays among others) that it was beyond the counter's register. The unexpected intense radiation in certain regions of space came as a shock, and cast doubt on the safety of a projected manned space flight. Several heavily energy-charged belts around the earth's Equator were detected and named the Van Allen belt, after their discoverer.

Space exploration was a turning point for auroral research which now became fully international. The form and limit of the earth's magnetic field, which had previously relied on calculation and hypothesis, could now be measured. The magnetosphere was also discovered as a protecting shield and field of energy processes. The image of the world had grown larger; it was no longer an isolated body surrounded by cold, empty nothingness, but was enveloped by a clearly discernable structure. The auroral researcher, Robert H. Eather, wrote about this event:

> Modern understanding of the aurora is tied up with our understanding of the magnetosphere as a whole. Even the word magnetosphere is relatively new in science having been coined by Gold in 1958 to describe the region of near earth space that is threaded by magnetic field lines linked to the earth and in which very hot or ionized gas dominates over the neutral atmosphere. It thus represents the outer limits of man's environment and is populated with ions and electrons originating in both the earth's atmosphere and the sun's atmosphere. It has become clear in recent years that the magnetosphere must be studied as a whole, as one single system of strongly interacting regions, none of which can be considered in isolation. Thus theoretical descriptions are almost prohibitively complicated, and a given observational manifestation such as the aurora is part of a complicated closed chain of cause and effect relationships.5

This page and the opposite page contain photographs taken in the evening at intervals of thirty seconds, with constant aperture and exposure, which show the building and reconstruction of auroral structures over the course of time. (Taken January 28, 1982, at Kiruna, Sweden, 68° N, looking north-east).

Solar wind

The discovery of the magnetosphere led in 1959 to the discovery of the solar plasma, also called solar wind. This was shown to be a stream of particles independent of the many known types of solar radiation, which are all related

to light; that is, from ultraviolet rays via visible colours to infra-red rays. All of these are related by travelling at the speed of light, about 300,000 km per second (196,000 miles/s). The solar wind, however, behaves like a plasmic substance; its particles can be measured and counted despite their incredible minuteness and insignificant dispersion in space. Despite their rarefied nature, their behaviour is extremely energetic, and a comparison of the solar plasma's velocity in space with terrestrial wind is not unjustifiable. The solar wind moves at about 200 to 1500 km per second (120 to 950 miles/s). Measured against light, this is very slow, about three hundred times slower than the speed of light, which suggests the transportation of substance, and, like the wind, its speed varies.

The solar plasma fills the solar system as far as the trans-Saturn planets, where it meets and holds back the cosmic radiation of outer space which is dangerous to life, thus protecting our planetary system. The solar plasma consists essentially of ionized hydrogen and helium. These rarefied elements speed through space as electrons and protons and transport the sun's magnetic energy and lines of magnetic force.

The electrons are negatively, and the protons (and ions) positively, charged; the whole stream is equally charged, thus confirming Lars Vegard's hypothesis.

The magnetosphere's structure has been researched with countless measurements showing it to be a hollow sheath full of energy systems surrounding the earth. But for external influences it would be identical to the earth's magnetic field, with polar cusps or clefts centred at the North and South Poles. However, the perpetually flowing solar wind changes the magnetosphere's form. On the sun's side the sphere is pressed down to about 60,000 km (37,500 miles), or about five earthdiameters, above the earth. On this boundary there is a turbulent entry layer, the magnetopause. For the most part, the solar wind flows along the magnetopause where solar and terrestrial magnetic lines merge into one another (see Figure 14). Away from the solar stream, the magnetopause is elongated into a hollow tail that stretches several hundred thousand kilometres into space to the orbit of the moon.

Dayside aurora

Hannes Alfven, a Swedish physicist, who received the Nobel prize in 1970 for his work in this field, discovered the relationship of the charge at the boundary of the magnetosphere, the magnetopause and the aurora's formation. For decades, it was unclear whether the ionized solar particles entered the magnetosphere with the solar wind in an indirect spiralling way and then produced the aurora on the terrestrial poles, or whether the solar plasma entered directly through the funnel-shaped polar openings of the magnetosphere to some extent.

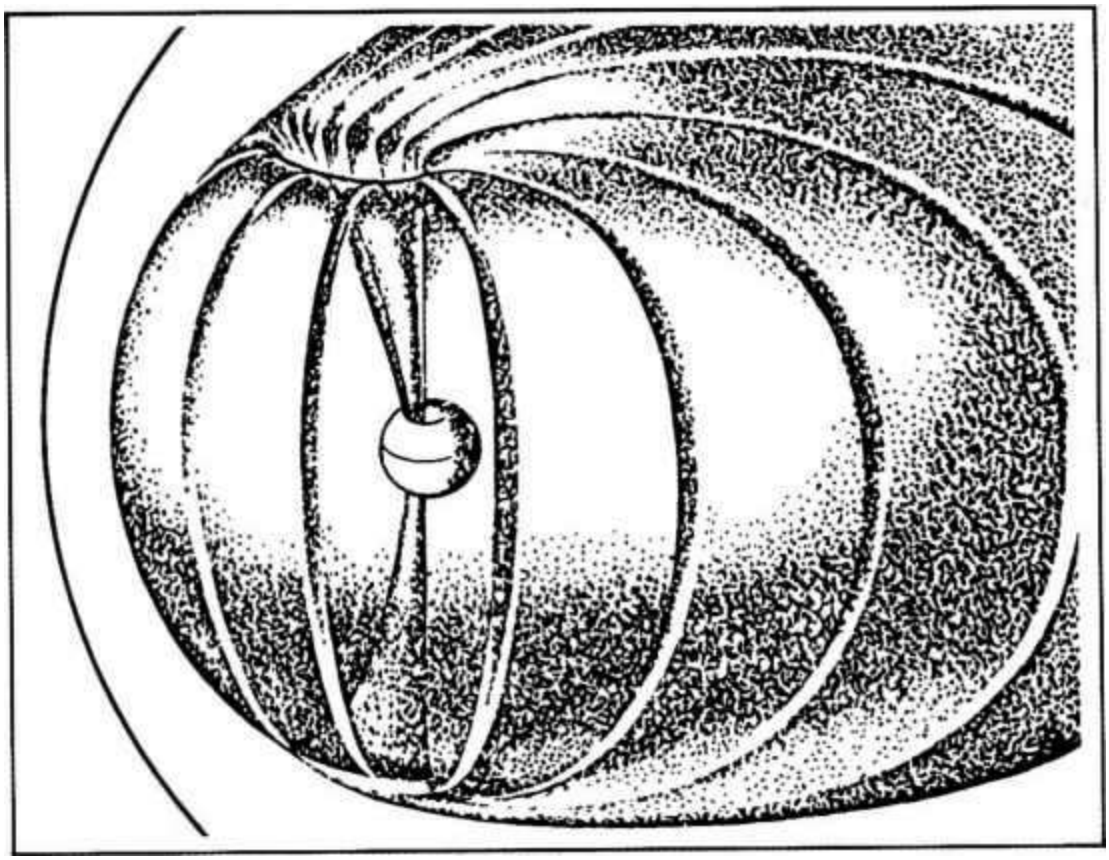


Figure 14. Magnetic field showing the polar cusp or cleft.

It is now clear that the stream of solar particles penetrates the open lines of magnetic force above the geomagnetic pole. In doing so, it fuses with the funnel-shaped, converging lines of force which act as a powerful brake. This gives rise to a barely perceptible, high aurora which fits into the vault of the heavens like a delicate pink cupola in the far North, around Spitsbergen, even during the dark, polar, winter's `day.'

This dayside aurora was first observed and measured in 1960, and is

occasionally visible to the naked eye. In this aurora, solar particles only possess the original velocity with which they left the sun, which is insufficient to produce the well-known, intensively luminous aurora.

Solar and terrestrial plasma

Within the magnetosphere there are powerful electromagnetic circulatory systems. The parts closest to the earth rotate with it. This is the plasmasphere around which the outer systems are formed, together with the boundary layer of the magnetopause; both are orientated towards the sun.

Within the entire magnetosphere there is also plasma which can justifiably be called solar-terrestrial plasma; in contrast to the solar plasma it can have peculiar characteristics and is concentrated in the plasmasphere as well as the Van Allen belts. The greatest concentration however, is to be found in a nucleus of the long magnetotail, which is named the plasma sheet.

When there is an intense burst of solar plasma, the earth's magnetosphere is energized and vibrates. In turn it enriches the magnetotail's nucleus (plasma sheet) and puts it under stress. The resulting discharge pushes the plasma simultaneously in the direction of the earth and in the opposite direction: out into space away from the sun. It is only when this happens that the solar-terrestrial plasma receives the energy and velocity to drive it from the sunless side to the polar magnetic lines, which appear in the evening and night sky as the aurora.

Closer to the earth, subordinate magnetic storms arise following the superimposed magnetosphere discharge, and appear as storm-like plasma eruptions. These sub-storms are visible as unusual auroral displays within the auroral oval (Figure 15). The origin of the magnetosphere discharges seems to be linked to solar activity:

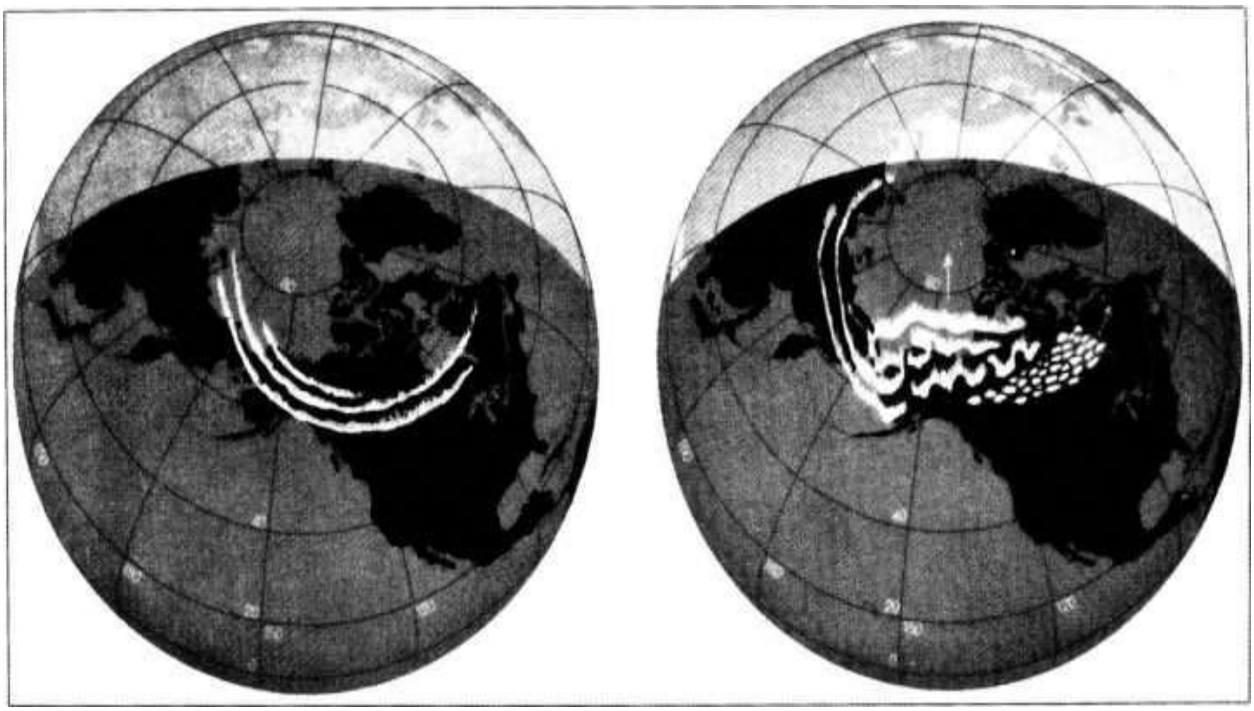


Figure 15. A composite sketch based on many photographs showing a magnetic substorm as it would be seen at a great distance from the earth. On the left, there are quiet auroral arcs within the oval. On the right, a substorm is rising; the arcs fold and begin to dissolve in order to distribute themselves more widely (from Akasofu).

> As a result, magnetic flux accumulates on the nightside until some form of instability triggers its release. In this process, some of the magnetic energy is converted to the energy of the plasma sheet particles in what may be the terrestrial analogue of a solar flare.6

The velocity of the magnetosphere plasma is several times that of the plasma coming from the sun. The enigma is: Where does this nucleus plasma, which is so rich in energy within the magnetosphere, come from? Solar wind either penetrates the pole's cusps and circulates around the mantle, or it merges with geomagnetic field lines at the magnetosphere. However, Robert H. Eather confirmed:

> A third possible source of plasma sheet particles may be the loss of the earth's own ionospheric particles along the open magnetic field lines from the polar cap regions.?

This third possibility suggests that the plasma of the magnetosphere's nucleus (the plasma sheet) could be called terrestrial plasma or solar-terrestrial plasma as it bears essential characteristics of solar plasma. While some auroral researchers leave this as an open question, others interpret it as great electric fields in the immediate vicinity of the earth's environment.

Conclusion

The discoveries of the most recent research have led to the view that the cause of the aurora is no longer to be sought exclusively in solar events, but within the terrestrial sphere itself. If the magnetosphere, described by Eather, is seen as an extended realm of the earth, then we can see how solar plasma is continually absorbed and accumulated in the terrestrial region, where it receives additional energy and thus becomes the plasma which is transformed into light and colours of the aurora in the immediate vicinity of the earth.

So, we can see the origin of the aurora in the earth's surroundings. However, one might ask whether the solar wind is not so much the cause of the aurora as the occasion for an, as yet unknown, sun-related occurrence on the earth, that gives rise to the aurora.

The visible aurora only constitutes one thousandth of the total release of energy. An average hour-long auroral display has roughly the same capacity as all man-made power stations - about a hundred million kilowatts. Magnetic storms that arise seriously affect radio communication. The induction current corrodes pipelines. To what extent this powerful energy can be controlled and used by man is a genuine and dramatic question for the future.

The supersensory and electrical powers that were initially seen as being in the hands of the gods for example, the lightning wielded by the Greek god, Zeus have over the millennia been transferred to human hands. Will a similar development take place in the future regarding the aurora? Even now, the aurora has inspired human beings to important new insights into the relationship between the cosmos and the earth.

5. The Sun — Planet and fixed Star

The aurora directs our attention to the sun, which can be seen as a fourfold structure: the surface layer of the sun (the photosphere); the flaming flare immediately around the sun (the chromosphere); the surrounding aura of light (the corona); and, the solar plasma filling interplanetary space (the solar wind). The sun's interior, which is neither perceptible nor directly measurable, is not considered here.

Photosphere and sunspots

Since the on-set of the scientific age, the visible solar orb has been correctly accepted as the real sun. It is from the surface of the sun - the photosphere - that the forces of light and warmth issue, generating life on earth. When the sun sinks below the horizon, the rays of light disappear and cold darkness spreads over the earth. The visible occurrences on the photosphere - sunspot activity - also reveal the structure and development of the sun, as well as establishing a connection with the aurora.

The dark sunspots are openings on the surface of the photosphere, allowing deeper layers of the sun to become visible. Just below the photosphere is the convection zone where the photosphere's granulated surface is formed. The dark spots are significantly cooler than the surrounding surface, and although the spots on the sun appear small when seen from the earth, they are actually immense. The dark nuclei of the spots (the umbra) have an average diameter of 20,000 km (12,500 miles), with the surrounding lighter penumbra about 50,000 km (30,000 miles). These dimensions are many times greater than the earth's diameter. The largest group of sunspots photographed had a diameter of over 300,000 km (200,000 miles) - almost the distance from the earth to the moon.

The red colour in the aurora usually has a limited spead; it seldom covers a wide area. In this photograph, taken at 10 pm in the Esrange Mountains in northern Sweden, the red streaming down to the horizon is therefore exceptional. It was accompanied by unusually strong solar activity, confirming the connection between the two phenomena.

Sunspot occurrences vary; some years there are none or few, others years a great number. After an interval of sunspot absence a new phase of sunspot formation begins. Sunspots originate in high latitudes (40° to 60°) on the solar disc. As a result of the sun's rotation the spots move from east to west, and approach the solar equator with increasing frequency, also forming groups. Their formation takes from two to three weeks, occasionally several months in the case of larger groups. The spots appear in pairs at roughly the same distance north and south of the solar equator, and are accompanied by strong magnetic fields; the pairs are themselves magnetically polarized (from one spot period to the next the polarization of the spot-pair is reversed). Somewhere in the region of latitude 15° the spot formation reaches its climax and then, as it draws closer to the equator, disappears again.

The time between one spot maximum and the next is between nine and thirteen years, on average just over eleven years. As a rule, the increase of the spots is more rapid than their decrease leading to a clear maximum moment. The time from minimum to maximum is only about three years; the time of its dying away about eight years. The Swiss astronomer, Rudolf Wolf (1816-93), made a count of sunspot cycles, beginning with the year 1755. Particularly high sunspot activity in our century was in 1917, increasing in 1937 and 1946 until the century's maximum in December 1957. Large portions of the sun were covered with gigantic spots. In 1976, a new sunspot cycle began, which reached an unexpectedly high climax in the summer of 1982, comparable to that of 1957. Most of the aurora photographs in this book were taken during that cycle. A new cycle began in 1998.

The increase and decrease of the sunspots is accompanied by other occurrences on the photosphere and their transition to the chromosphere. In the immediate vicinity of the spots particular eruptions take place - the flares. These are short-lived radiation eruptions, whose duration is between a few minutes and, at most, an hour. Widespread fiery eruptions are continually taking place on the sun and are visible in the thick flaming surface of the chromosphere surrounding the photosphere. Immense formations tower up within these projections There are arc structures, often many hundreds of thousands of kilometres in length. However, the specific eruption of `flares', takes place in direct relation to the spots, and are a sign of increased solar activity.

The spots and spot groupings move from east to west. As new spots form in higher latitudes, the general picture is of a westerly diagonal movement of the spots towards the solar equator. The immense protuberance arcs reach out from the equatorial region in the opposite direction to the spots.

The discovery of sunspots, following the invention of the telescope around 1600, was profoundly disconcerting for Christian scholars in western Europe. When the Jesuit priest, Christoph Schemer (1575-1650) reported this revolutionary discovery to his Father Superior, he could only refer to Aristotle; yet reading Aristotle's work from beginning to end and finding nothing about spots; the phenomenon could only be ascribed to a fault in Schemer's glasses or his eyes.

This clear observation of sunspots shook man's belief in the sun as the pure illuminating foundation of being, since these dark patches appeared to be quite out of character with the nature and spirit of the sun. Added to this was the fact that, until quite recently there had not been a scientific theory to explain their appearance.

J.V. Evans describes the present state of sunspot research as follows:

> In the convection zone the energy density of the gas motion greatly exceeds that of the solar magnetic field, and thus the motions tend to organize the fields. (Whenever the energy density of the ionized particles in space greatly exceeds that of the magnetic field, the field must follow the particle motions as if frozen into the medium.) The reverse is true in the chromosphere and corona, where the motion of the completely ionized gas is confined and controlled by the magnetic field. Sunspots are thought to be cool regions where the magnetic fields at the photosphere are strong enough to influence the convective motions and upward flow of heat. The 11-year cycle in their number and latitude on the disk may be a result of an observed differential rotation of the convection zone with latitude; the equatorial regions rotate faster than the poles. This differential motion is thought to twist the sun's dipole field until loops or knots of field lines break through the photosphere.'

Sunspots constitute one of the biggest riddles for modem astronomy, and lead to the fundamental question: how should the sun be defined - is it a

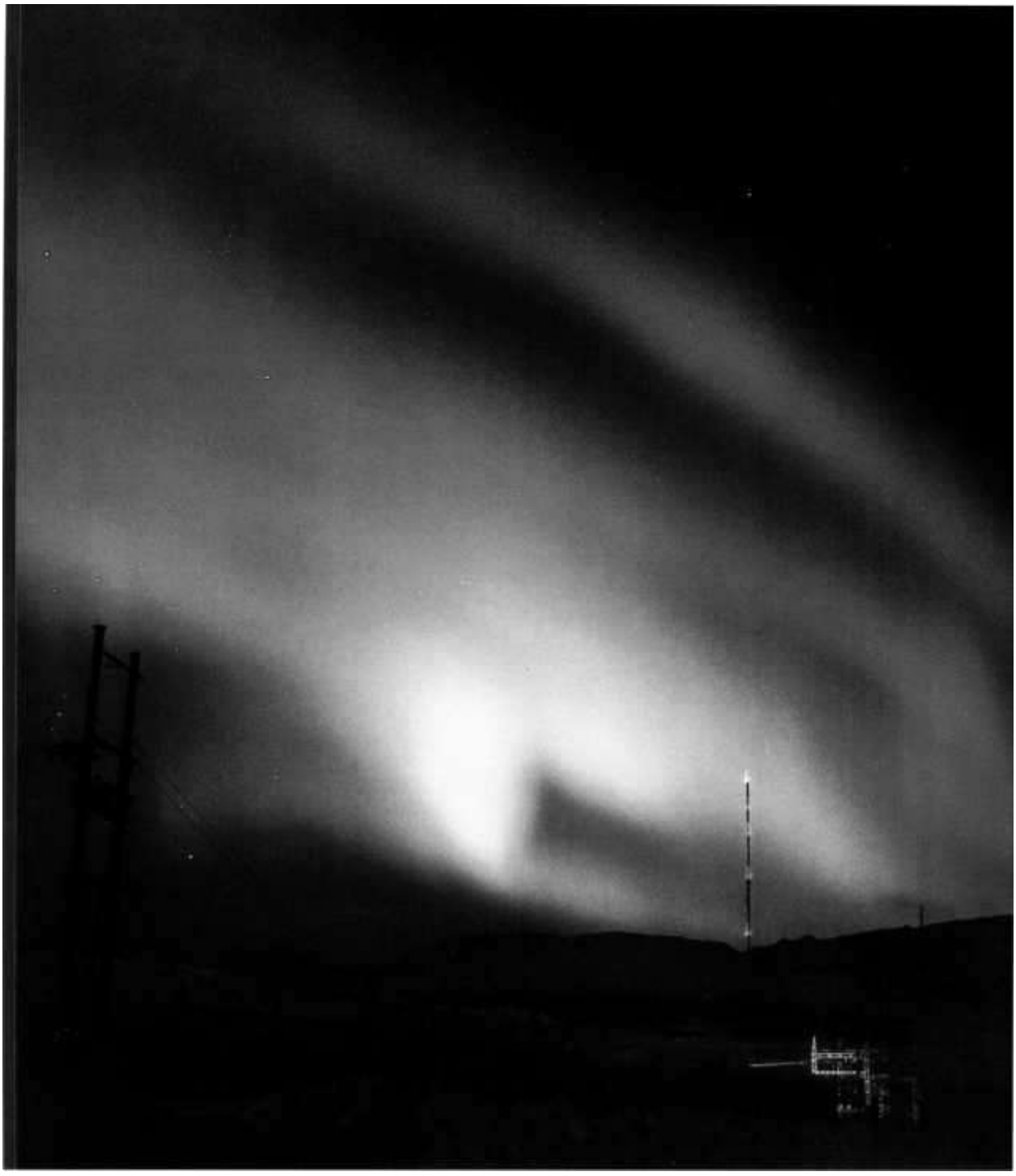
planet (moving luminary) or a fixed star? To find a solution, the sun must be considered as a whole. It is already known that planets or satellites are round, self-contained bodies and do not have their own light source; the moon is the most obvious example. The sun is surrounded by a number of such moving luminaries which, together with the sun, form the planetary system of which our earth is also a planet. The present, outermost boundary of this system is the orbit of the planet Pluto, which is forty times further from the sun than the earth. Fixed stars, on the other hand, lie at incomparably greater distances from the sun. They are self-luminous and barely move in relationship to each other; even with the most powerful telescope, they appear simply as points of light without form or shape.

It is true that photometric investigations (measurement of light values) of double stars, together with calculations of slowly progressing fixed star movements, such as those of Sirius, reveal that these stars also have a similar structure to the sun. These investigations are further confirmed by spectroscopic measurements which show, on the basis of the accompanying Doppler effect, that one part of the star moves away from the observer while another part moves towards the observer, as is the case of the rotating sun. These observations suggest a similarity between the fixed stars and our sun, but that is only one aspect of the sun.

In earlier times it was self-evident that the sun was a planet like the other planetary bodies. This was not an expression of ignorant naivety that had as yet no actual knowledge of the stars; it resulted from immediate experience. Even when the sun was regarded as a special moving luminary, its connection with the other planets was so important that this acquiescent affinity allowed it to be viewed as a planet. The sun's and moon's exact coincidence of size and shape, which is evident at an eclipse of the sun, fitted the sun naturally into the order of the planets. Thus the similarities but also the differences of sun and planets is essential to our planetary system; they underlie the varied pattern of their movements, and ultimately affect the origin and continuance of life.

The movements of the aurora behave in the sky rather as water does on earth and star constellations do in the cosmos, often forming spirals and whirlpools. The latest measurements show that the inner structure of the aurora has a spiral character. Separate appearances have been called 'curls.'The foldings and unfoldings have a breadth of about 1 km, with

roughly 5 km (3 miles) between each one.



The aurora's arcs and bands can be drawn as thin veils of colour over a large part of the sky. Then, all the colours of the spectrum can appear. Starlight penetrates the veils and reaches the earth. In this photograph, on the left around the dark pylon the constellation of Orion can be recognized. High on

the right, above the illuminated transmission mast at Kiruna, is the constellation of the Bull.

Expanding stars, condensing planets

In what follows, the term star is used not only to represent the body of a star but also the surrounding light and radiance. The universe is permeated with dispersed plasma. We will refer to these phenomena as expanding star processes corresponding to ancient experiences of the influences and effects of the stars. Together with light and heat activities these star-processes show, in extreme cases, the total dissolution of substance in black holes.

In contrast to this is the planetary condensing process, shown in spheroid bodies of concentrated matter.

From this viewpoint the unique position of the sun is that it is both a star and a planet, thus uniting opposites. It is a star because through intense light and heat activity it dissolves all substantiality in space, while, at the same time, it is a planet that has a substantial spherical form. Throughout the sun's composition the star and planet interact continually, above all in the photosphere, and remain in a harmonious state of balance.

This equilibrium can be seen in the sunspots. Despite initially leading to the false conclusion that the sun was threatened with extinction, the luminous photosphere as a whole does not diminish in brilliance. The sunspots are surrounded by broad zones of particularly bright flares whose area is twenty to forty times greater than the enclosed umbra (the dark nucleus) of a sunspot. Thus the surplus of flaring brilliance compensates for the absence of light from the spots. The solar disc, therefore, shows no sign of decreasing light, nor a loss of heat.

This is confirmed by the fairly constant amount of energy arriving per square centimetre per minute, on earth from the sun, as measured at the atmospheric perimeter.2 A slight fluctuation of one thousandth of this solar constant would produce far-reaching climatic changes.3

Recent results of solar research show that the sunspot rhythm is accompanied by a transition from one light process to another. When the

solar surface is free of spots, the blue part of the spectrum, coming from the interior, increases. At maximum sunspot activity the red light of the chromosphere grows.4

In the photosphere's alternating rhythm between being free of, and filled with, sunspots, the sun demonstrates in time what is already discernible in space as a duality of planet and star. Planet and star processes alternate in a living rhythm. In the photosphere's star-process phase, the solar wind is particularly intense; producing widespread tensions in the terrestrial magnetosphere, and resulting in the the aurora on the earth's circumference.

The corona

This rhythm is also revealed in the sun's corona which appears during a total eclipse as a bright but delicate light surrounding the darkened solar disc. It can also be seen with a coronagraph, a telescope with a built-in arrangement to cover the sun's disk.

Light itself is invisible and we can only see it when substance is illuminated. The corona is visible because the light shining from the sun's photosphere makes the interplanetary material, which surrounds the sun, luminous. During greatest sunspot activity - that is, when the expanding star-process on the photosphere develops - the corona encloses the solar sphere like a compact luminous spherical flower (Figure 16). On the other hand, when the photosphere again attains its spotless, radiating planetary form, the corona spreads out, winged and star-like, far into planetary space and can reach the earth (Figure 17).

Thus the sun shows opposing tendencies: if the star process begins to develop more vigorously on the photosphere and chromosphere, then the corona adopts a planetary, round, enclosing form, thus enveloping the solar sphere. Conversely, once the sun has again closed up its torn surface and re-established the planetary figure, the corona discloses a star-process: radiating out and creating the star-like balance to the consolidated, planetary solar sphere.

The changing shape of the corona imitates breathing - maximum sunspots represent the inhaling sun. As with human respiration, this solar `breathing in'

is also quicker than the `breathing out.'

During sunspot minimum when the sun is `breathing out,' the corona radiates into the stars. At the same time, the aurora recedes from the earth. Conversely, during sunspot maximum, the corona contracts like a `breathing in,' and the auroral oval becomes stronger, expanding towards the Equator. We see here an intimate relationship between solar and terrestrial processes which makes it difficult to regard them separately.

Another area of similarity is on the corona where there are hollow spaces similar to the sunspot `holes,' which appear to be concentrated in the sun's polar regions during the sunspot minimum, and diminish during an increase in spot formation. On earth, the aurora is correspondingly at home in the polar regions and is an expression of solarrelated star processes. Equally, the hollow structures in the sun's polar regions reflect further cosmic star processes, which pass over directly into the solar wind, particularly through the holes which are formed in vast areas of the sun's corona. Through the intimate relationship between sun and earth seen in the auroral process, we can begin to discern an all-embracing solar-terrestrial organism.

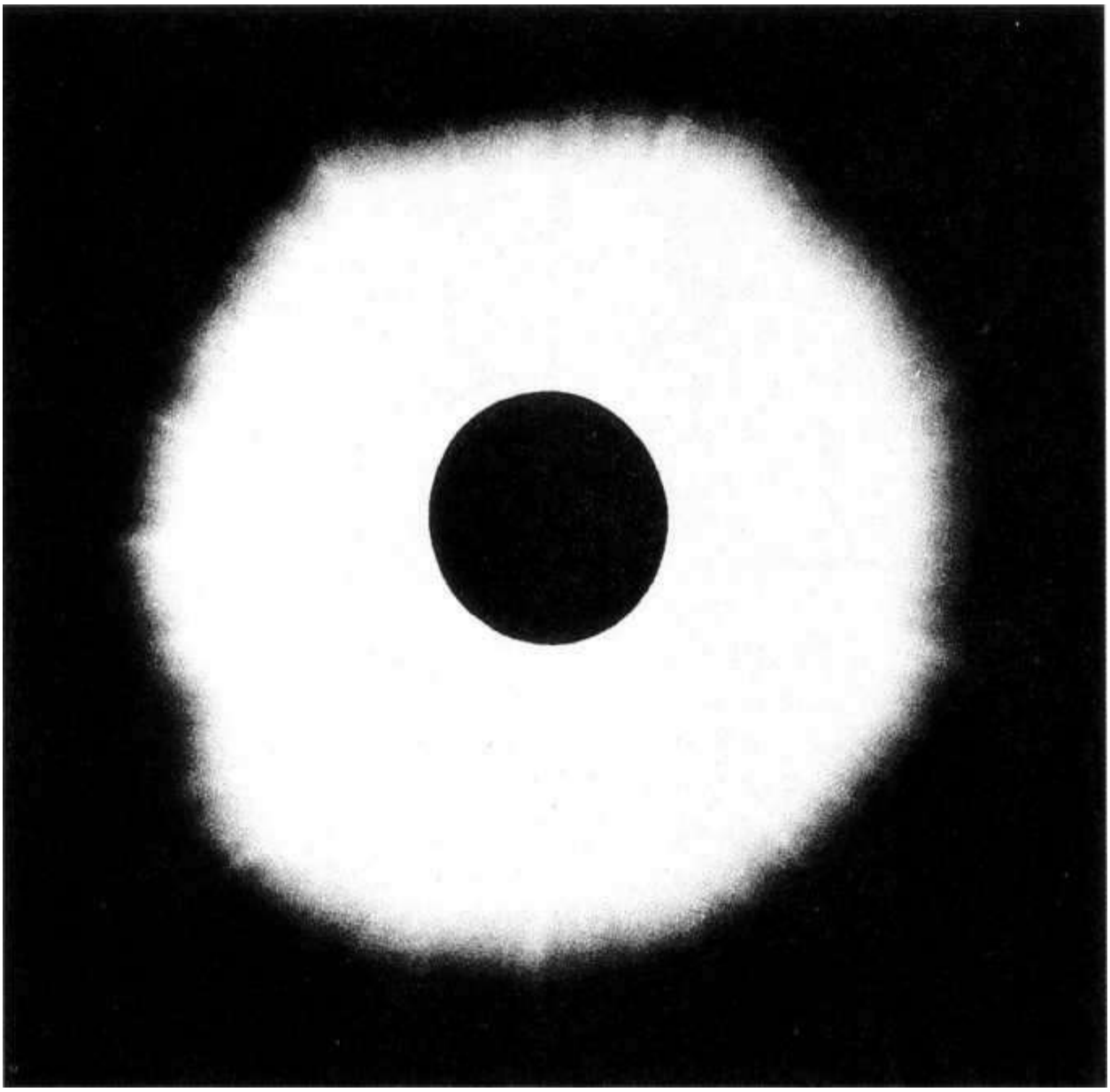


Figure 16. The sun's corona shows the spherical form typical of maximum sunspot activity. It also reveals the impressive size of this corona, showing that the planetary condensing process of the corona is active even at a great distance from the surface of the sun. The expansion of the corona to its maximum visible size is subject to strong oscillations.

Recent research, shown in the results of the German-American Helios spacecraft programme, has unexpectedly shown that the solar wind itself has `holes' which are completely devoid of solar plasma. This surprising discovery confirms and broadens the picture given here of the sun's complementary expanding star-process. In every sphere of the sun hollow

structures can be found.

The largest amount of matter in space consists of plasma similar to that of the sun. Syuin-Ichi Akasofu, a well-known Japanese auroral researcher, writes:

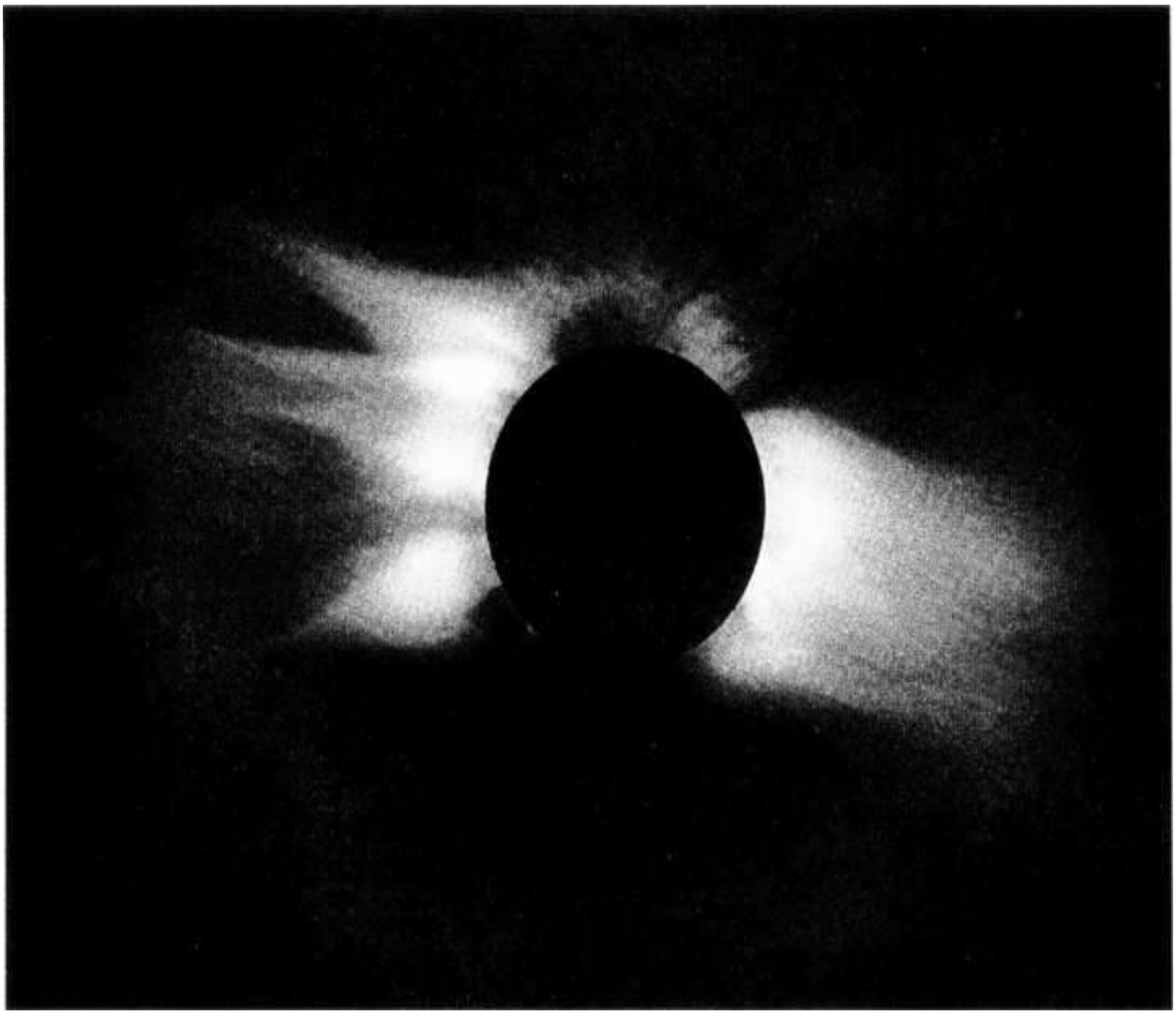


Figure 17. A photograph during the solar eclipse of June 30, 1973, during a phase of sunspot minimum. The widely spread out asymetric, wing-like and starlike forms of the corona are characteristic of this phase. They can range over distances as great as that to the earth and so fill a large part of the solar system. This phase of the corona can be described as a more expansive `star process.'

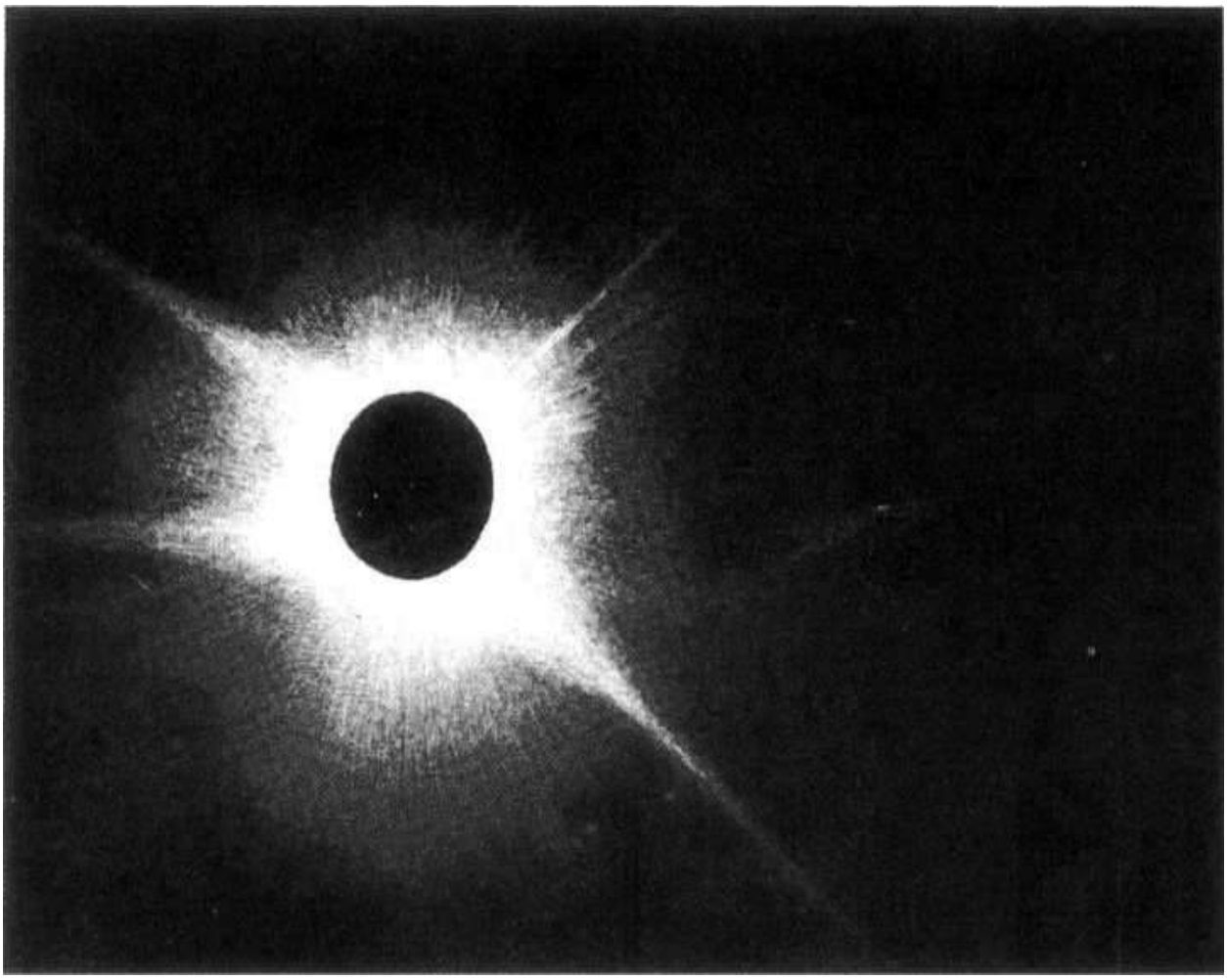


Figure 18. Since the inner part of the corona is ten thousand times brighter than the outer part the corona form cannot be captured by an individual photograph. The above picture of the solar eclipse of January 22, 1898, five years after a powerful sunspot maximum, shows a form typical of sunspot minimum, where the streams of the outer corona can be seen straetching out to a distance of fifteen sun radii.

> Therefore, this extreme condition of matter is of fundamental importance to an understanding of almost every aspect of astronomy, such as the formation of the solar system, various processes in the sun, stars, quasi-stellar objects, pulsars and galaxies. The auroral plasma is the only one in nature that can be studied directly by satellite-borne instruments (except for information gathered by occasional visits of space probes to some of the other planets)'
>
> ... Some auroral scientists believe that basic plasma processes associated

> with solar flares are similar to those of auroral phenomena. Some also believe that by studying the auroral plasma we can better understand how the solar system evolved, since it must have been formed by contraction of a huge plasma cloud.6

Akasofu portrays the aurora as a window to the hidden mysteries of the solar system.

Anthroposophy and aurora

Rudolf Steiner (1861-1925) through his spiritual research, or anthroposophy, throws light on some of these mysteries. He describes the evolution of the earth in four stages Old Saturn, a phase consisting of a large body of warmth; Old Sun, a gaseous warm body; Old Moon, a state in which liquids appear, and our present earth (including all its geological eras) where solid matter is formed.

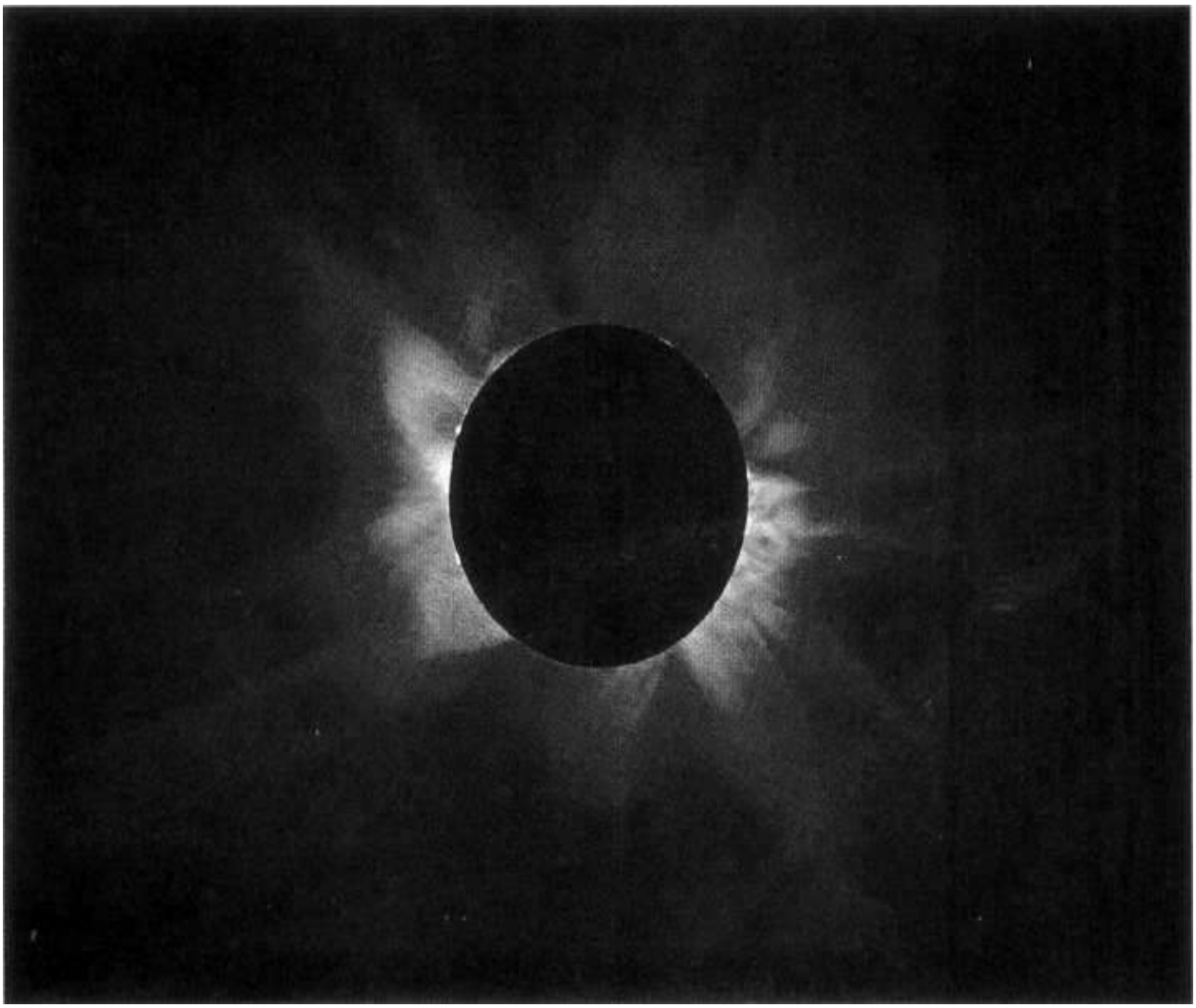


Figure 19. This photograph of the a total solar eclipse on February 16, 1980, reveals the sun-process described in the text, The eclipse occurred at the time of the most recent sunspot maximum. The picture omits the spherical, flower-like form of the corona, as it was taken with a camera specially adapted for red light (24 second exposure). By using this technique the fine structure of the corona is visible for the brighter light of the spherical form is cut out. This fine structure shows itself to he star-like. In its expansive working into the photosphere (and out again) this characteristic is revealed in sunspots.

The creative forces that lead to solid forms in our present earth phase are spiritual beings which Rudolf Steiner called Spirits of Form, and the Bible calls Elohim in the plural. The choir of the Elohim is the creator of our present world, as well as the surrounding planetary bodies including the sun and its visible photosphere, whose relationship sun with the earth is obvious.

The earth only experiences light, warmth and life when the sun rises. The part of the sun corresponding to this present earth phase is the photosphere which shows the most solid aspect.

The previous phase of creativity, Old Moon, has no direct relationship with the present lunar body, which in the sense of what has been said above, is also an expression of the present state of the earth. During the Old Moon era, fixed forms had not yet arisen. The activity of movement predominated, though form was already emerging. One can therefore discern a half-formed, primordial world where intensive dynamic occurrences were working creatively within, and on, an incipient world of forms. The spiritual beings working here are the `Spirits of Movement' or Dynameis. Rudolf Steiner describes this phase of creation as follows:

> To the supersensible observer of these processes, it is as though organs were opening out and drawing to again, while a warmth-giving stream pours in and out of them, and air and water substances are conveyed inwards and outwards ... Manifold processes are taking place within [the vapour-like environment]. Substances are combining, substances are separating; some parts grow more condensed, others thin out, become more tenuous.?

Something similar can be perceived within the sun's chromosphere. The flame-like phenomena are insubstantial forms undergoing dynamic changes. They spread round the sun like a wave-tossed sea, out of which violent protuberances rise up as gigantic arcs of fire penetrating far into the surrounding corona. One might question whether the fire substances originate in the solar body itself or come from the sun's surroundings (corona), solidifying on the protuberances. These extremely dynamic events embody the character of the `Spirits of Movement,' the Dynameis.

The sun's corona is the lofty and radiant expression of the sun's aura which has been known and revered since ancient times. The changing corona-form during one phase (sunspot maximum), concentrates on the centre by enveloping the sun's body like a sphere, and at another stage (minimum) it opens up, star-like to the surrounding universe.

There is a correspondence to Old Sun where the transition from warmth

and movement strides further into light. This occurrence is accomplished by hierarchical beings, the `Spirits of Wisdom,' Kyriotetes Wisdom and light are two manifestations of the activity of these beings. Rudolf Steiner explains:

> Let us imagine the Spirits of Wisdom situated at the centre of the Sun absorbed in contemplation of the vision of the sacrificing Thrones [even higher hierarchical beings]; and by reason of this vision, radiating forth their own being; and receiving back their radiating being which they sent forth, receiving it reflected back from the surface [from the inside of the surrounding sphere], so that they receive it back as light. Everything is illuminated. What then do they receive back? Their own being surrendered by them became a gift to the Macrocosm, it was their inner being. Now it rays back to them; their own being meets them coming back from outside ...
>
> The inner and the outer are the two opposites which we now meet ... and `Space' is born!8

In this sense, we can see the corona process as an image of Old Sun events. In the corona, energetic warmth processes generate a space-filling dynamic of light, alternatively radiating and contracting.

The solar wind, with the solar plasma, issues from the corona and streams through the whole planetary system. Planetary space remains dark, for the plasma is not light and unlike the corona, not even lightrelated. On the contrary, this stream of ions and protons consists of matter. The solar wind carries ionized particles along with it, such as hydrogen and helium, and moves with fluctuating velocity bound to magnetic forces, whereas the plasma is influenced by the photosphere's sunspots. The direction of the plasmic stream is affected by the magnetic fields of other planets, and the plasma in the earth's magnetosphere produces the light and colour of the aurora by colliding with highly refined terrestrial matter.

The solar wind fills the inter-planetary space which was once occupied by the even earlier phase of Old Saturn which reached the present orbit of Saturn. The solar wind process can thus be regarded as an expression of this evolutionary stage. In this first era the foundation was laid for material substance - `Old Saturn' was a darker body of warmth:

> A life of light begins, flickering here and there within the Saturn world and dying down again. At some places a quivering of glowing light will appear, at others something more like rapid lightning-flashes. The Saturn warmth bodies begin to glimmer and glisten, even to radiate light.9

This could almost be a description of the aurora. The streaming solar wind carries the seeds of light, which under certain conditions appears as the aurora, producing the overwhelming profusion of light and colour like a shining echo of the far distant past of Old Saturn.

6. On the Nature of the Earth

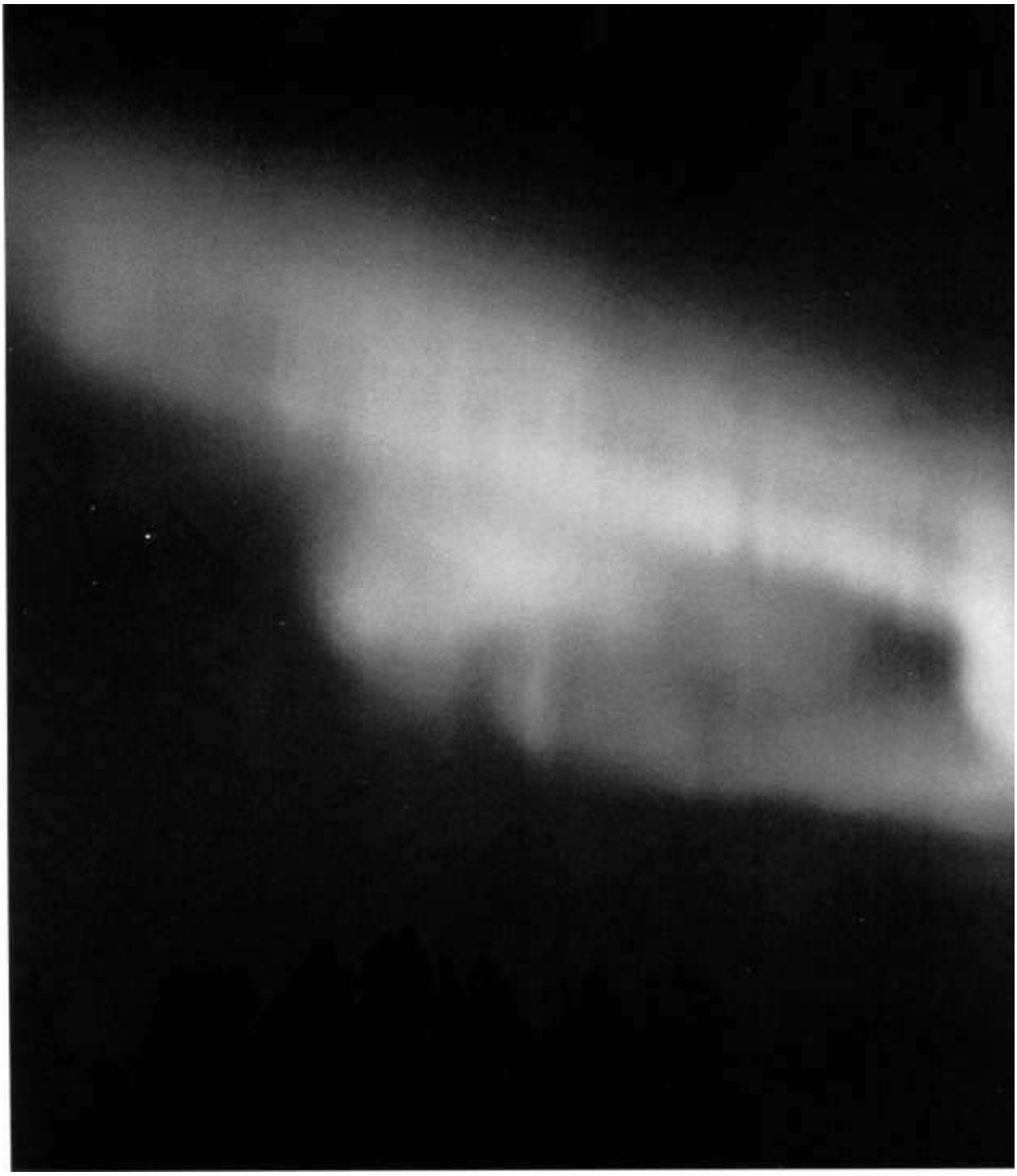
The aurora develops over the landscapes of the North and the Antarctic continent. Even though it is not yet completely understood, we shall now look at these regions in the context of the earth's life-structure. Several phenomena found at latitude 60°, show this to be a threshold.

From latitude 60° it starts to be continually light at the height of summer. The daily rhythm begins to disappear leaving this region more open to planetary rhythms.

In the atmosphere, the prevailing westerly winds, of temperate zones below latitude 60°, meet the easterly polar winds in what meteorologists call the Polar Convergence Zone. Here, there is an area of friction and convergence that produces cloud formations and establishes weather patterns. The aurora can frequently be seen in this zone.

All these phenomena are indications of a changed life-structure hidden from our everyday perception. In Chapter 2 these occurrences were briefly outlined, and in the prehistoric age of myth, were perceived clairvoyantly and described in images. The `grinding Sampo' of the Kalevala is the perceptible, mythical expression of this occult process. The Sampo itself was perceived as an image of the rotating earth's continual encounter with a sphere of forces that enveloped it, and at this light boundary - latitude 60° the impression of a grinding process arose. Towards the end of the Kalevala the combination of forces underlying this Sampo image is clearly indicated: `From these seeds the plant is sprouting,/Lasting welfare is commencing." The seeds' origin is the supersensory realm from which life itself comes forth, a realm also called the etheric world in anthroposophy. We refer to this world when the we use the term `sphere of forces' or `lifesphere' of the earth.

This photograph, taken in November 1979, shows parts of an arc encompassing the night sky. These arcs can stretch more than 1,000 km (600 miles). Within the arc a band has built up into a spiral as a result of intensive movement. The true extent of these powerful arcs and spirals cannot be grasped by the human eye.



A beautiful example of a spiral form taken on by a far-stretched auroral curtain (see also page 94).

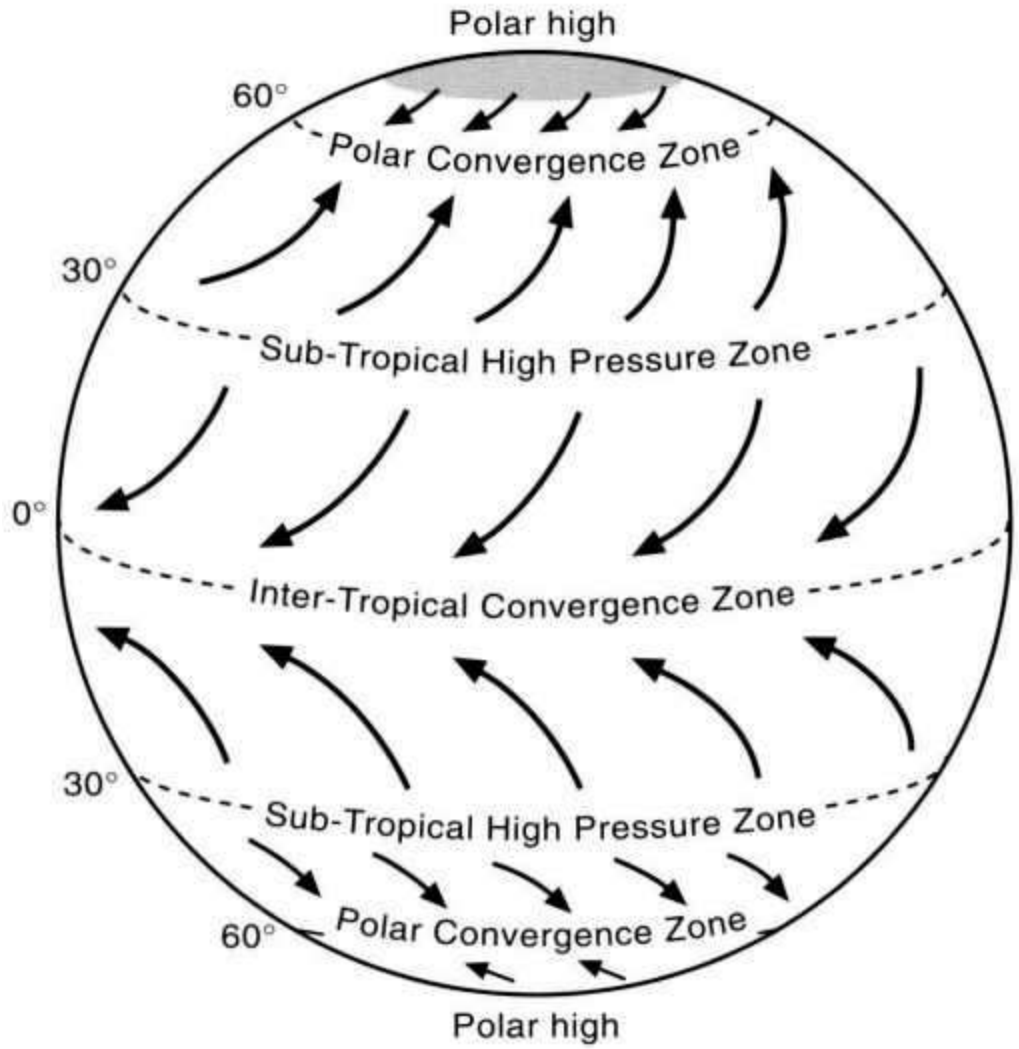


Figure 20. Patterns of prevailing winds across the earth.

Atmospheric changes

A manifestation of this sphere was ascertained scientifically over two hundred years ago, when regular atmospheric pressure fluctuations were observed, later termed the semi-diurnal pressure wave In the morning and evening pressure rises slightly; in the afternoon and after midnight it decreases correspondingly. Up to the present time, the causes of these fluctuations are not fully explained. Johann Wolfgang Goethe (1749-1832) concluded that these atmospheric pressure changes did not have their cause outside, but within the earth itself: `We seek, therefore, the causes of the barometric changes not without, but within the earthly sphere; they are not cosmic, not atmospheric, but terrestrial.'2 With this, Goethe discovered a

previously unperceived life-condition of the earth.

While the semi-diurnal pressure wave is clearly discernible, weather variations cause much greater changes in pressure. The barometric fluctuations take place along the earth's lines of longitude. Atmospheric pressure reaches its height towards nine o'clock in the morning; after that it falls to a low point at about three in the afternoon. The same thing is repeated towards nine in the evening and three in the morning. We can imagine a wave of air pressure moving twice daily around the earth. This happens quite independently of the seasons.

However, the maxima and minima of the pressure wave are greatest at the Equator and decrease in higher latitudes, dropping sharply at latitude 60° and disappearing entirely at the poles. This is an expression of the sphere of forces, which not only influences living things, such as plants, animals and humans, but also the atmosphere and weather patterns. This rhythmical sphere is described in detail by Gunther Wachsmuth (1893-1963), who calls it the `respiration sphere.'

Wachsmuth imagined a spatial image of this supersensory sphere which, being a bit larger than the earth, and eccentrically displaced, left part of the earth outside the field. The sphere is roughly aligned with the sun but displaced by an angle equivalent to about three hours: the sun's meridian passage is at noon, and the sphere's meridian passage at three in the afternoon.

The portion of the earth outside the sphere always lies in night's darkness. If the sphere were visible, at the Equator we would see it coming towards us at about six o'clock in the morning, like a mighty wave from the East. As it ascended, the wave's inner side would be fully visible at nine o'clock and would show its greatest rate of change, resulting in maximum atmospheric pressure. After this, the pressure slowly decreases again, while the sphere moves further upwards. At three o'clock it reaches its highest position at an altitude of about 70 km (45 miles); the rate of change slows and stops, and atmospheric pressure sinks to its lowest level.

Towards evening, the sphere sinks further and at nine o'clock attains the greatest variation, causing maximum atmospheric pressure. Thereafter, the

earth begins to rotate out of the sphere. By three in the morning the sphere sinks below the earth's surface to about 23 km (14 miles), when atmospheric pressure reaches its second minimum.

Human life is influenced by the rhythm of the sphere of forces. In the morning, from eight to ten o'clock, the human being is most efficient. From about midday, there is a `sleepy' crisis, lasting until about three. Following this, a phase of mental awakening begins which reaches a high point at around nine and then fades away again later in the evening. A repeated crisis at three o'clock in the morning is not usually noticed by a sleeping human being, but is the hour when night-workers have greatest difficulty in keeping awake. This ebb of energy is also reflected by the fact that it is often the time of human death. These rhythmical effects of the sphere of forces mould important life processes, even in the formation of the embryo, and so strongly influence the nature of the human being like a pulse acting from without that infiltrates the basic framework of the human constitution.

The red upper part of this auroral curtain occurs through the emissary of oxygen at heights of up to 400 km (250 miles). (Photograph taken by Riidiger Gerndt in February 1981 in the Esrange Mountains, northern Sweden).

The life sphere, being bigger, is permanently above the surface of the earth in latitudes higher than 600. At latitude 60°, it moves from east to west,

resulting, therefore, in particularly strong, etheric activity which penetrates the polar cap. The lower altitude of the forces-sphere also causes a concentration of these forces at the polar caps. This phenomenon is described by Wachsmuth as follows:

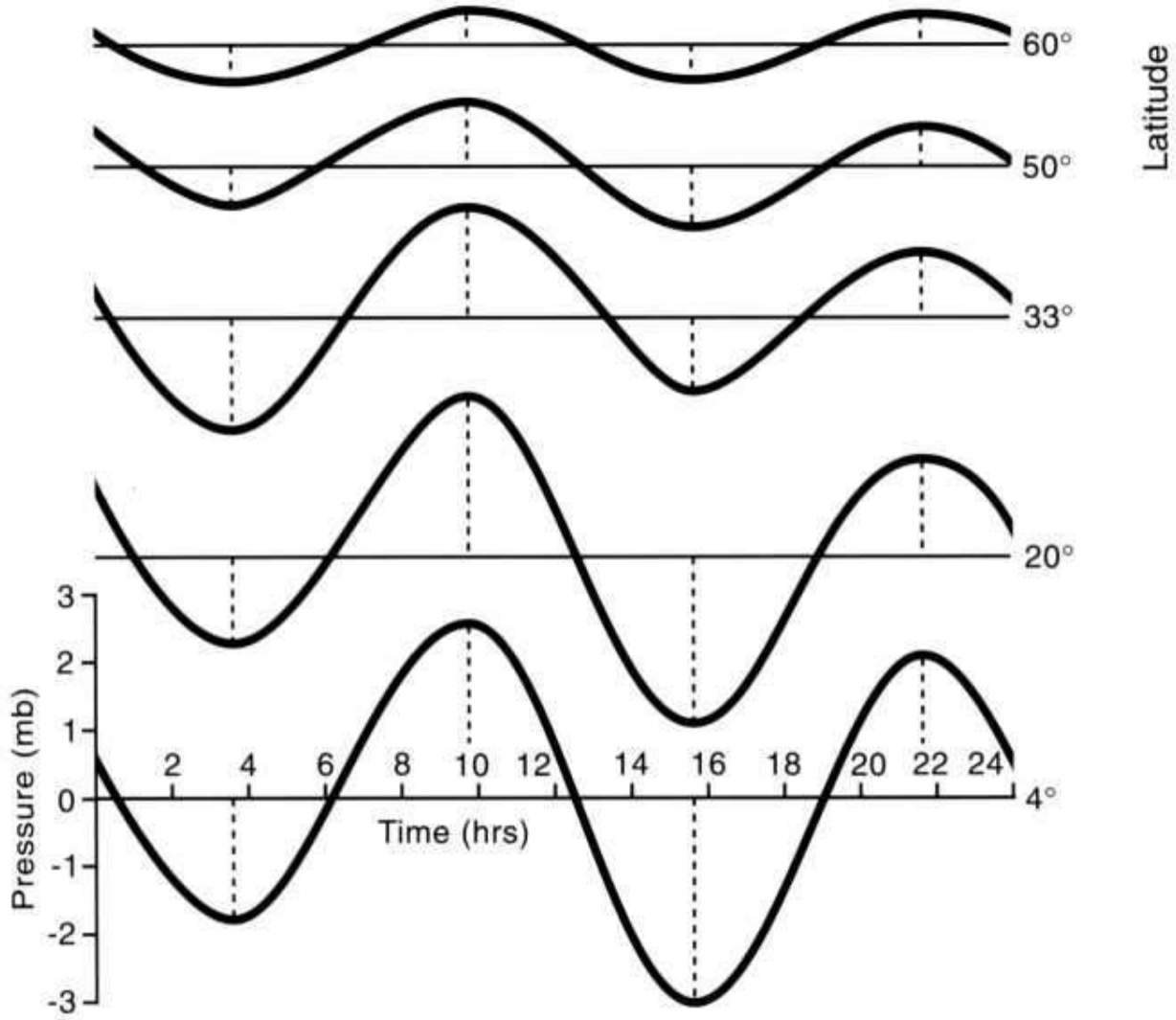


Figure 21. Semi-diurnal air pressure waves at different latitudes.

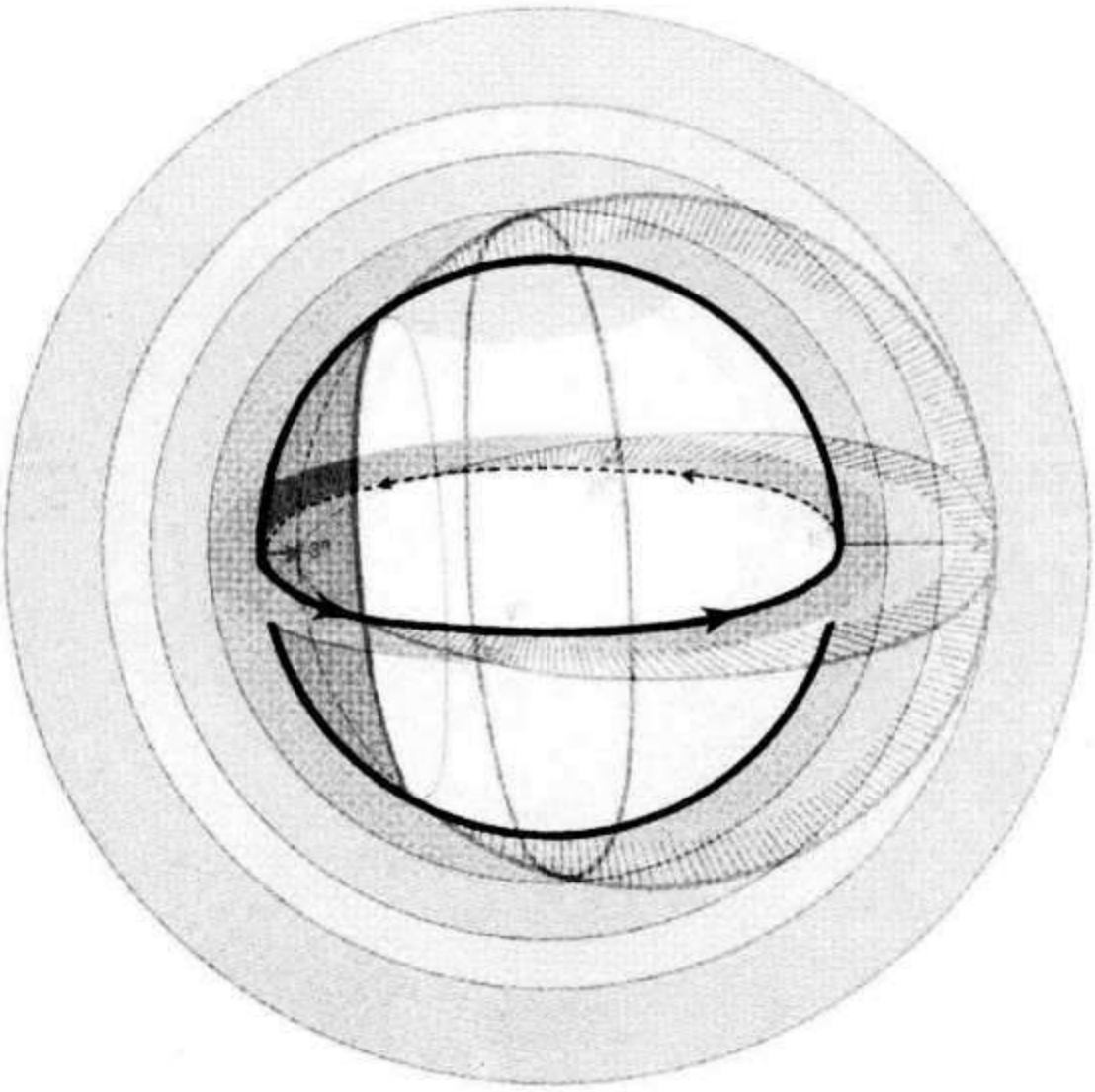


Figure 22. The sphere of forces ('respiratory sphere') of the earth organism during the course of a day. On the left, part of the earth (black outline) lies outside the forces sphere at night. On the right, the forces sphere has `breathed out' and finds itself above the earth's surface in daylight. Extreme positions are at 3 am and 3 pm.

> The cupola of forces, which is only slightly arched over the polar regions, embraces a compressed body of air. The effect exerted by this field of force moves in an east-west direction during the course of the day; that is to say, counter to the earth's rotation about the pole. There arises thereby a kind of circling, gliding movement around the edge of the polar cap ... In this way, this cupola of force mould ever anew the air

> body contained in it with its impulses as it moves round the polar caps. On the edge of the body of air a contour-forming and structuring impulse occurs, while this contoured body of air is moulded continually from without towards the inside, plastically formed, and guided to structural changes. The moulding activity of such spheres of force from outside
>
> inwards presents a graphic image of the efficacy of the formative forces described above. These forces lead here to the formation of elastic structures and to the fashioning of contoured organs inwardly changeable.3

Here, grinding and moulding events are described in almost the same manner as in the Sampo story of the Kalevala which describes the production of inorganic and organic structures and substances is described during the forging of the Sampo.

Electromagnetic variations

The concentrated life processes within the polar caps are accompanied by increased electric and magnetic occurrences. Electricity and magnetism are always present in all forms of life. In parallel with the forces' influence in the morning and evening there is also greater electric tension: the electric potential between different layers of air, and the earth's surface reaches its maximum at these times, with corresponding low points in the afternoon and after midnight.

This semi-diurnal fluctuation of vertical, electric potential, like the variations of atmospheric pressure, is greater in the earth's equatorial zone and decreases towards the poles. In polar regions - as with air pressure - there is slightly higher electric potential.

The magnetic fluctuations during the day also correspond to the sphere's basic rhythm. Thus in Europe the compass needle's North Pole is deflected more strongly to the East at nine o'clock, while at three it swings towards the West again. Fridtjof Nansen had already drawn attention to the magnetic pole's daily fluctuations in relation to this basic rhythm.

More noticeably, the phases of change in the magnetic field were discovered. Following on from the work of Birkeland, Leif Harang, a Norwegian, discovered magnetic oscillations. Harang called them sinusoidal oscillations other researchers called them giant micropulsations Their reversal occurs at three o'clock in the morning coinciding with the turning of the submerged forces-sphere, and the high points of fine magnetic oscillations are discovered at nine o'clock in the morning and evening.

Within the polar regions there is a concentration and slowing down of all processes, but the independent rhythm of the sphere of forces remains. The maximum height of the sphere which reaches 70 km (54 miles) at the Equator is only about 35 km (22 miles) at latitude 60°, and at the pole itself, remains constantly at about 16 km (10 miles).

The auroral ovals are formed around the geomagnetic poles and are thus offset in relation to the caps, coinciding with the sphere's basic rhythm. A typical auroral display begins in the early evening when the sphere of forces is coming closer to the earth's surface. The most intense aurora usually lasts until midnight, during the time of greatest altitude change. After midnight, the sphere is closest to the earth (or in latitudes lower than 60°, below the earth); at the same time, the aurora fades. The reverse occurs towards three in the morning when sphere begins to rise again.

The aurora's appearance is not caused by this rhythm, unlike the effects described earlier. The coincidence arises because both the auroral oval and the forces-sphere are aligned with the sun while the earth rotates.

The auroral oval ring is narrow on its solar side and much broader on the opposite side (see page 79). So, the auroral phenomenon on the night side appears above the lowest part of the sphere. This broad part of the oval moves from latitude 60° in North America (Hudson Bay) through 70° (north coast of Alaska) in the Arctic Ocean, stretches up to 80° (Severnaya Zemlya, North Land), passing Lapland (70°) in Northern Europe, before returning south to Hudson Bay at 60°. To an observer in northern Scandinavia the auroral oval appears to come from Spitsbergen during the day (where it is always found), moving towards northern Norway, and then turning back again at midnight. At midday, its boundary is again located over Spitsbergen.

The polar cupolas produce a concentrated tension as a result of the continuous grinding process where the sphere enters the earth. The forces, that are only apparent for a few hours during heightened phases in more temperate latitudes, are continually active here; there is constant high pressure and electrical tension.

The peculiar characteristics of polar regions with their ever-present electric field of tension can be observed between the earth's surface and the ionosphere. In tropical regions the magnetic field lines lie parallel to the sphere's surface, preventing interaction of terrestrial forces and cosmic forces. The forces-sphere of the polar caps is maximally compressed and enclosed within itself and the magnetic field. Thus, in the intermediate regions, an encounter takes place between the forcessphere and the high-reaching ionosphere, which often gives rise to a dramatic clash between these polarities. The auroral process allows this encounter to become visible.

Appearance of the aurora

It is an idiosyncracy of the aurora that it appears quite near to the observer. It has a relationship with the earth and a particular panorama, in the same way that cloud formations belong to certain landscapes. Some auroral displays that appear at considerable altitudes, while others envelop mountains or seem to touch the observer. There are also more subtle perceptions, such as accompanying sounds whether these are subjective hallucinations or objective sounds of discharging magnetic fields is of little importance. The observer stands within the auroral display and the peculiar etheric landscape that belongs to it. He is not separate from the aurora, but consciously and empirically involved in the event. We can compare the experience with dreams: the dreamer senses events outside themselves, but at the same time, is aware that he takes part in producing these events or is even the cause of them. Thus visual exposure to the aurora recognizes its other-worldly grandeur, but cannot confirm the its great distances from the earth.

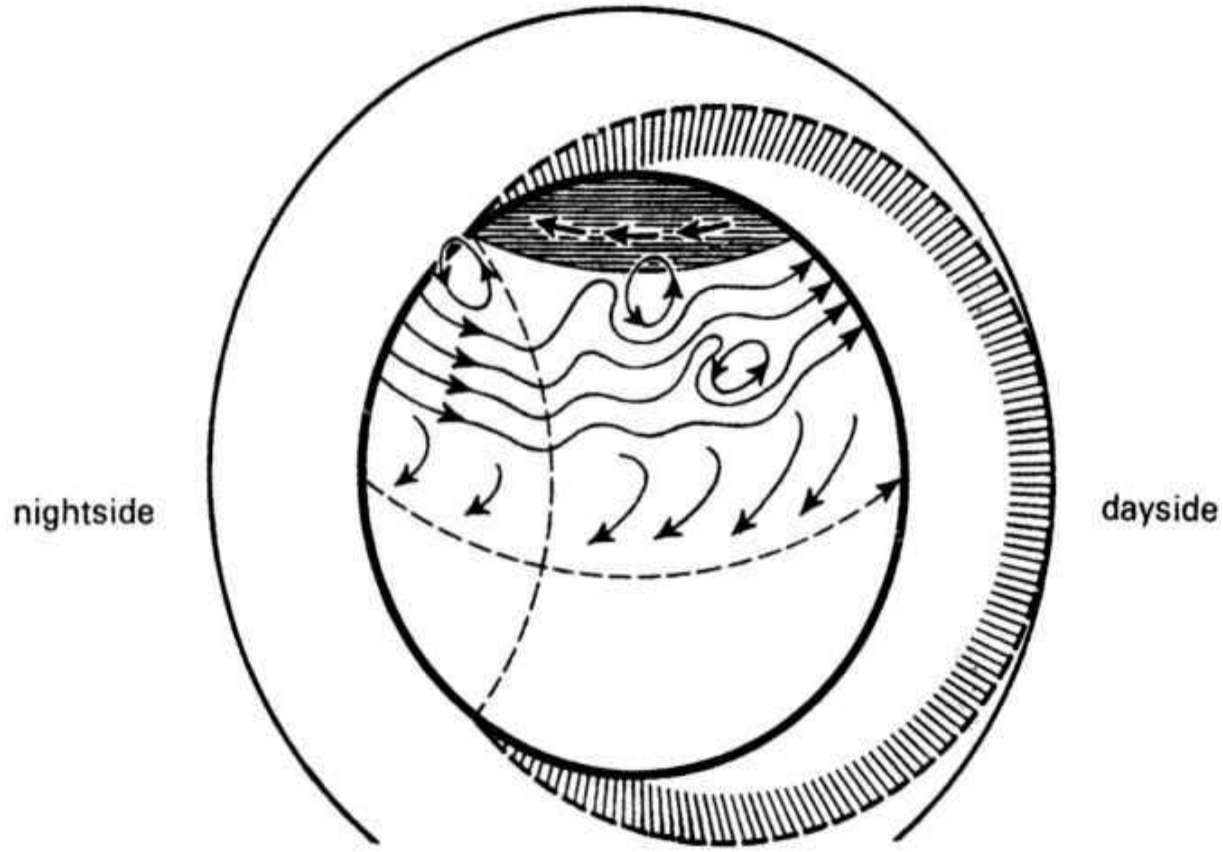


Figure 23. The formation of waves and cyclones in the general atmospheric circulation.

The cosmic-terrestrial image of the development of the northern lights is becoming clearer. The auroral ovals take form as blossoms of light and colour above the earth's polar regions. Pale red solar plasma flows into the centre of these blossom-structures from the high realms of the sun, and fills the auroral curtains with solar processes flowing from the heights into the depths, invisible to the naked eye. The curtains penetrate the earth from the wide circle of the self-enclosed magnetosphere, and their buckled and folded vertical walls stretch vertically across many hundreds of kilometres. It is these, which are perceived above all in the visible auroral landscape.

The curtains grows narrower towards the bottom as they follow the field lines converging on the geomagnetic pole. The force-structures of these field lines connect the auroral ovals with specific magnetic structures in the polar regions. At the same time, matter (for example, atoms of oxygen and nitrogen) moves upwards on the paths of the field lines into the auroral

curtains. Within the blossom-like oval structures a profusion of forms comes and goes in a glowing, radiating wealth of colour, appearing on the mobile geomagnetic field and the part of the earth's atmosphere where colour also arises.

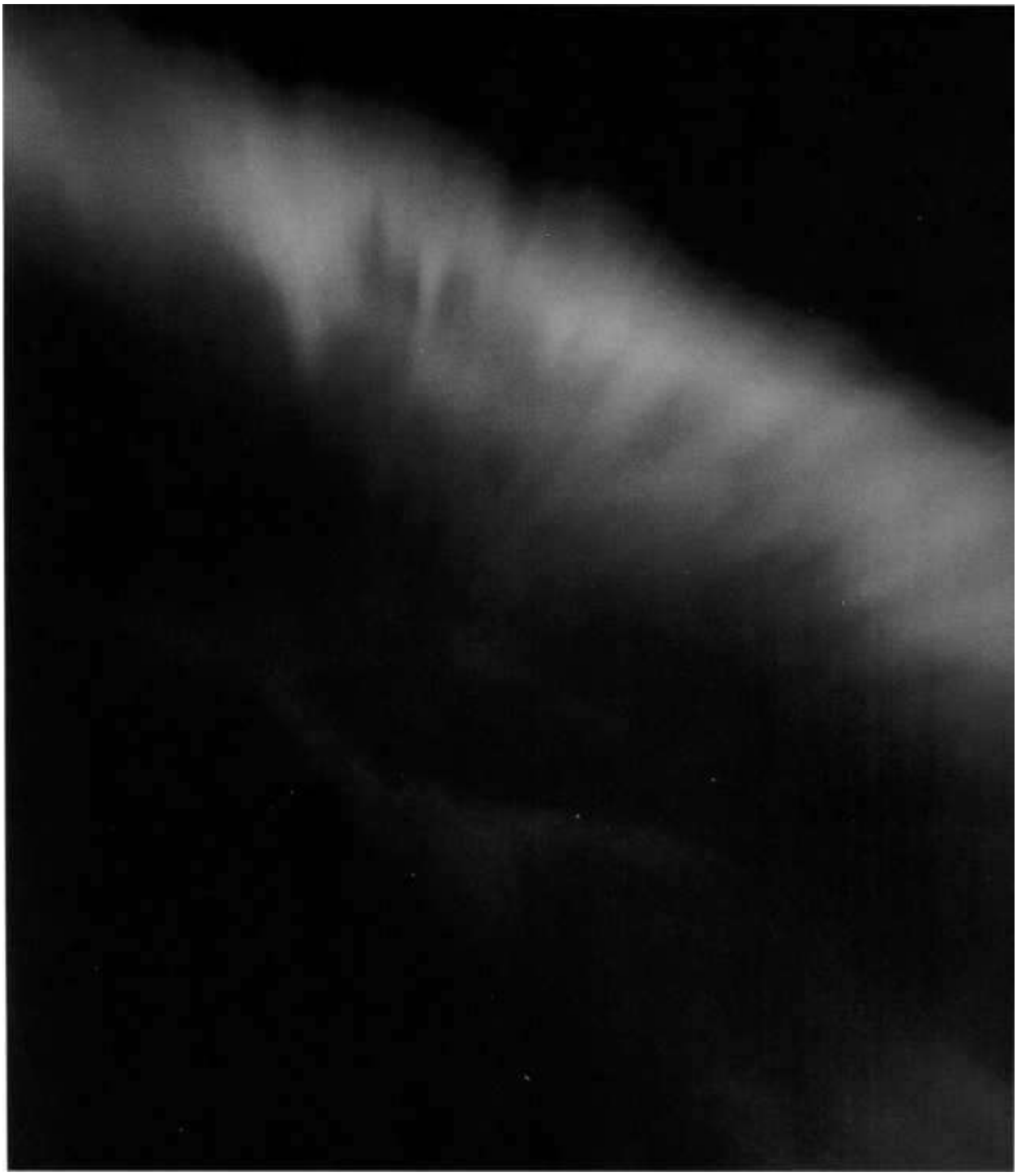
The ovals expand and contract rhythmically and spontaneously, in conjunction with sunspot rhythm and consequent eruptive plasma-expansions in the magnetosphere. In this way, they continually manifest solar activity and terrestrial processes. These dynamic events only appear as moving, colourful formations via the magnetic fields of the sun and earth. Wachsmuth's description of the significance of magnetism is therefore characteristic:

> The study of magnetism is instructive for our conception of the world, because we are here concerned with an operation that does not have the monotonous uniformity of gravity, for at the basis of magnetic phenomena there are great variations during the course of the day, and so on. However, there is also not such a turbulent and disintegrating effect as with, for example, heat, but in magnetism there is present a unifying, co-ordinating tendency with great mobility in a living manner. Gravity tends to only draw things together, heat tends to dissolve; gravity alone would lead to a conglomeration and stagnation, heat alone to chaos. Magnetism tends towards unification and yet allows thereby for variation and mobility. At the same time, it is directive and therefore regulating and formative and thus a many-sided aid in the arranging of the earth's organism.4

These cosmic-terrestrial magnetic effects are brilliantly and uniquely displayed in the form of the dynamic, elusive aurora.

The auroral corona gathers itself together dramatically like a cloud centre. Its midpoint looks towards the north, below the constellation of Cassiopeia. With the bright star in the lower section of the picture, above the tree tops, the constellation of Andromeda begins. The constellations are only seen in these positons in the extreme north. At the same time further south they are

below the horizon. After the formation of a corona the aurora in northern Europe usually fades away.



Like afar-reaching wreath in the sky this auroral corona embraces the constellation of the Great Bear (the four stars can be seen in the bottom left with the three `tail'stars to the right). The last of the `tail' stars, Benetnash,

shines through the rim of the radiant blue wreath. The rays are curved curtains, stretching up for many hundreds of kilometres and emerging from the celestial North Pole below and to the left.

7. Lightning, Rainbow, Aurora

Lightning, rainbows and the aurora together form light and colour phenomena in the earth's surrounding atmosphere, from the black-blue of the thunder-cloud, the bright daylight blue of the rainbow to the midnight blue forming a background to the aurora.

The connection between lightning, rainbows and the aurora was first described by Walter Biihler as metamorphoses of sunlight. Much of the following is based on his account but with the evolutionary aspect placed in the foreground.

Lightning

Early people interpreted lightning as the display of higher divine forces. The Greeks described their highest god, Zeus, as the Lightning Thrower. What was seen, in past times, as an act of God, is today seen simply as an electrical phenomenon. However, the precise origin of lightning remains obscure.

The particular clouds in which lightning originates can best be observed in tropical regions where they often give rise to daily thunderstorms. In these regions the sun's rays penetrate almost vertically to the earth's surface and heat it up. This results in the surface air warming up, expanding, and rising since it is lighter.

Close to the ground, hot air absorbs large quantities of moisture which it takes up into high altitudes. However, in ascending the air cools and is no longer able to carry the moisture. It condenses as vapour and a cloud begins to form. The more moisture taken up and released the greater the cloud formation. We then get characteristic cumuli and later cumulo-nimbus clouds - the thunderstorm clouds which tower up in great billowing formations. Cooling increases steadily on the way upward; with each kilometre the temperature falls initially by about 10°C (5.5°F per 1000 feet), decreasing at higher altitudes to 3°C per km (1.6°F/1000 ft). Depending on thermal conditions, freezing-point is reached at a height of about 5 kilometres (3 miles).

The air's powerful updraughts accelerate and can attain speeds of up to 30 metres per second (70 miles per hour) in the central column of the cloud formation. In these turbulent updraughts, ascending vapour can become supercooled, passing eventually from vapour to ice at temperatures below freezing point. When these tiny ice crystals are formed, some scatter upwards. Only then, does lightning flash from the cloud, and torrential rain and hail occur, having attained this critical point of development

Whether cumulo-nimbus thunderclouds are seen meteorologically as turbulence, thermodynamically as a heat machine or an electrical generator, we are still unable to explain the origin of lightning. The gradual growth of the cumulus cloud resembles the growth of a flower or tree. The hot air is sucked up from all sides as through a network of roots; the puffed up, horizontal accumulations of cloud that spread out from the `trunk' evoke an image of foliage. Then, in high altitudes, the ice crystals forming and shooting out at the top we see something similar to a blossoming and seeding. Thus the whole formation of a thundercloud shows a tendency common to all organic forms - a distinct structure incorporating contrasting conditions, or polarities; a plant with flower and root, or a human being with head and limbs.

There are many polarities in cloud formation. In lower regions we find warm air with its associated characteristics of expansion and mobility, and in higher regions cold and its characteristics of concentration, shaping and hardening. as we can see in the formation of ice crystals. There is darkness and condensation of matter within the cloud's high altitude, where otherwise light shines and matter is dissolved; at lower altitudes there are upward draughts of dynamic warmth where usually static horizontal layers predominate. The thundercloud disengages itself from the suuroundings and becomes an independent organism.

There is an electric field between the earth's surface and the upper atmosphere, called the ionosphere. Pure air insulates and shields living things from the electric currents. However, natural radioactivity and cosmic radiation (as well as pollution) cause a decrease in the air's isolating capacity. This leads to continual electric currents, flowing with a strength of around 1,500 amperes bridging the potential difference between the ionosphere and

the earth's surface of at least 250,000 volts and reducing the electric charge. The electrical potential increases with altitude, so that a person at sea level is in a quite different electrical field from a person standing on a mountain top. This potential difference is about 100 volts per metre (30 V per foot). Consequently, a standing person is under a charge of 150 to 200 volts from head to foot, but when lying down this potential difference is not there. The strength of the flowing current is, in this case, spread out thinly through space. It is within this electric field that the thundercloud grows. Measurements have shown that lightning flashes from the cloud only when the temperature reaches freezing point, that is when the formation of ice commences at an altitude of several kilometres. The ice-forming stage in the development of the cumulo-nimbus cloud is therefore simultaneously the generation of lightning.

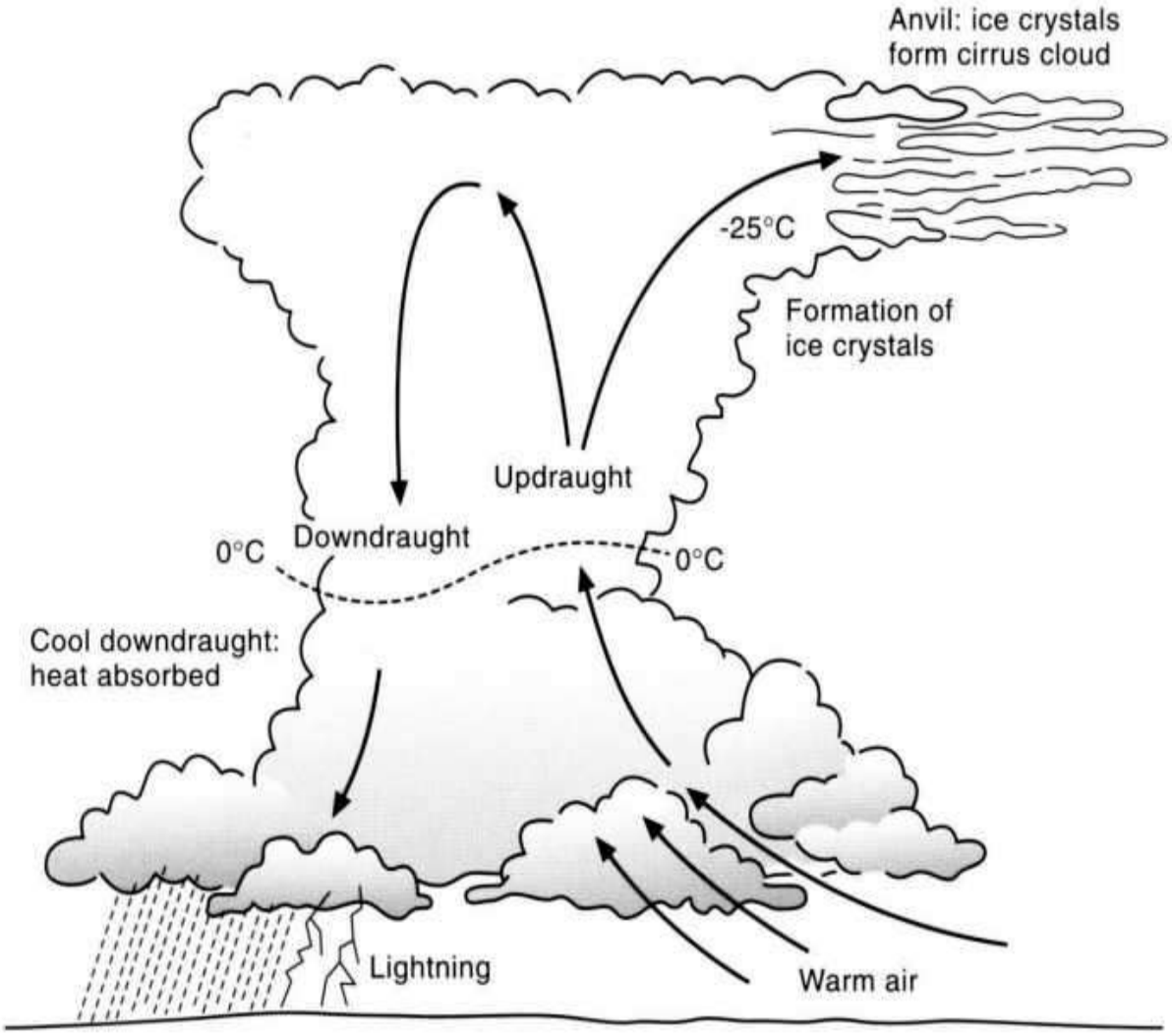


Figure 24. The formation of a cumulo-nimbus cloud.

When this electric field is looked at from a spiritual aspect, then we find a similar polarity to that of the previous chapter. The mineral world subject to gravity, leads to solidification, concentration, and finally to the formation of matter; the etheric forces lead to expansion and dissolution, and finally the formation of a vacuum. Without this duality of etheric world and the realm of matter no organic forms would arise on earth. The apple growing on the tree needs material processes and gravity, as well as the forces of expansion. The area of tension between the material and the etheric world is the biosphere This tension, however, has a built-in tendency to disintegrate which is an expression of ageing or other circumstances such as pollution or the destruction of the atmosphere. The visible expression of the disintegration of etheric light forces is the phenomenon of lightning.

Lightning shows no gradual development but is suddenly there; it bursts forth from a pent-up, invisible charge in a place that cannot be determined in advance. Light and darkness have no influence on its generation. Lightning's basic direction is downward. Both the electrical build-up of the cloud and its discharge in lightning run vertically. However, lightning soon changes its initial direction. Photographs show how lightning constantly seeks new paths through the air. Lightning streaks during a thunderstorm reveal that they have no spatial orientation; the display is chaotic.

Lightning grips the air's matter and changes it through combustion. It can melt rocks, and even destroy life. When the total picture of thousands of streaks of lightning is frozen in a photograph, it is as if the air were full of glowing roots or an illuminated network of veins. The air appears to be impregnated with creative fire forces moulding the substance of the world. This can be experienced after a thunderstorm: not only is the air cleansed by the rain that gives rise to this new lease of life, but nature is felt to be born anew.

On the one hand lightning appears strange and frightening; on the other, familiar and liberating. It is frightening because it seems to destroy the harmony of nature, but often the aftermath produces a feeling of release and liberation. Within ourselves we have something similar to lightning: will-power and anger. Anger, an uncontrolled display of will-power, also starts

like a flash of lightning and then expresses itself indiscriminately. However, it can also reveal itself as an expression of will aimed at legitimate conciliation. Anger then acts as a liberation when it re-establishes a harmony of spirit.

Geographically, lightning is particularly prevalent in a belt around the Equator between latitudes 20° north and south. In any place within this region lightning occurs roughly between one hundred and one hundred and eighty days a year, which means that in certain seasons it happens daily. Within the region as a whole there are over eight million flashes of lightning a day. In Australasia, this tropical storm belt extends from Bombay in the north, through Indo-China, Indonesia, Borneo, Melanesia, to the north and east coast of Australia. There is an area of concentration over Java where there are thunderstorms on more than 220 days a year. In Africa, the belt is mainly present between Madagascar and Natal, as well as the west coast in the Gulf of Guinea. In America, the northern part of the belt is displaced northwards, covering the Caribbean Sea from the north coast of Venezuela, through Central America to southern California, Texas, Louisiana, and Florida, with an area of concentration around Panama. South America is less affected by the belt, which shows itself in Central Brazil and on the coast from Rio de Janiero to Buenos Aires. Latitudes 20° to 30°, both north and south, are transitional regions in which thunderstorms are less prominent.

Within the earth's thunderstorm belt, storms gather during early afternoon following the midday heat. In certain tropical regions, thunderstorms always take place at a certain time, with almost mechanical rhythm. Lightning occurs during the sun's peak, darkened and cooled only by the stormclouds. The thunderstorms provide effective protection against the sun to processes on the earth's surface. Here, tropical life develops in the thunderstorm's shadow and the flash of lightning.

In the inhabited areas of these regions of our planet, the start of earth's development can be seen, as can the origin of key human epochs up to the historical introduction of Indo-Germanic peoples into India. These old cultures and inter-related peoples are an expression of the nature-forces surrounding them. In this particular case, one can speak of an ancient humanity under the direct influence of the will of a nature still united with

God; its distinctive mark being the lightning which expressed divine will. This distant human era can be referred to as the Lightning Era. Remnants of this period were preserved by the Etruscans, who attempted to forecast the future from lightning.

This part of an auroral corona stretches acros the sky like a mighty wing, with its centre in the north. Such a majestic appearance of an auroral corona is seldom seen.

Rainbow

In contrast to the drama of the thunderstorm the rainbow appears like an enchanted vision. A bridge of colour stretches effortlessly over the earth arching weightlessly across the sky. The radiance of its seven colours shines as though illuminated from within and without; the colours blend into one another. The rainbow resembles a vision more than a physical object.

The rainbow is a child of sunlight and the earth's watery atmosphere. The centre of the rainbow is hidden below the horizon, at the `anti-solar point', exactly opposite the sun, as far below the horizon as the sun is above it. The rainbow's complete colour spectrum is like a painted echo of the sunlight spread before the sun.

The arc often follows a thunderstorm in the late afternoon. When in temperate northern latitudes, the sun is in the south-west the rainbow then appears opposite, in the north-east. In summer, when the sun is high in the sky, the rainbow is low. As the sun sinks, the rainbow rises until, shortly before sunset, it reaches its most impressive altitude, about 42°, approximately half-way to the zenith. As the sun sets, the rainbow fades and disappears. Following sunrise in the north-east, the rainbow may again appear high in the sky in the south-west; then, if the right weather conditions prevail, in the early morning hours it moves across the sky, always opposite the sun, descending northwards. When the sun reaches an altitude of about 42°, the rainbow sinks below the horizon. At midday, the time when lightning tends to occur, the rainbow cannot appear since the sun is too high for it. The rainbow can only rise agin in the afternoon above the north-eastern horizon.

The rainbow's main period is not during summer, but in spring and autumn. At about latitude 48° (Paris, Munich, Vienna, Volgograd in Russia, Newfoundland, Vancouver in Canada, Stewart Island in New Zealand) the midday sun in spring and autumn, stands at an altitude of about 42°, and potentially the rainbow can proceed on its course continually from west to east during the day, just dipping below the horizon at noon. As the days get

longer and the sun rises higher the rainbow sinks for a time below the horizon in the north (south in the southern hemisphere). At the summer solstice it is hidden for the longest amount of time.

The rainbow occurs when the moisture in the atmosphere precipitates as raindrops. The droplet forms the basis of many atmospheric phenomena. For example, when we go through a dew-laden meadow or wood, we see the drops sparkle with a variation of colour; each drop mirrors and refracts the whole environment. The sun's rays that strike the droplet exactly in the middle and penetrate it are reflected by the concave interior of the droplet and returned in the same direction. The bright diamond-like flash within the dewdrop appears exactly opposite the sun, or at the anti-solar point. Other rays falling on the droplet are first refracted (bent inwards) by the droplet's curved surface; secondly, reflected inside the droplet; and thirdly, as they emerge from the droplet, they are again refracted, resulting in an emerging angle of 42° to the sun's rays.

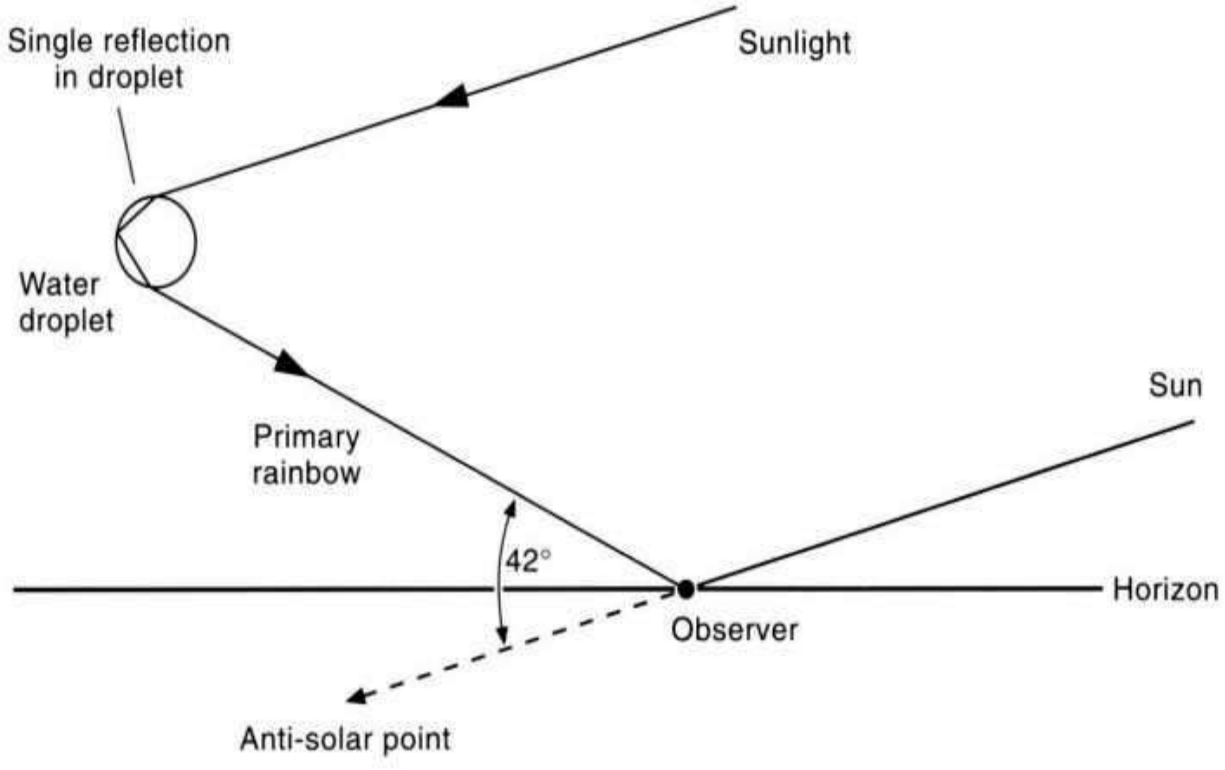


Figure 25. Refraction and reflection in a single water droplet, which forms part of a rainbow.

As in a prism, where each colour is refracted differently, so in a raindrop the colour spectrum appears as a colour cone instead of a band. The rainbow needs a space filled with a veil of water droplets. In each droplet the same thing occurs as in the dewdrop: the colour cone is rayed out to the sun, and together the myriad of drops make the rainbow appear.

In the larger, secondary rainbow, light emerges only after a second reflection inside the droplet at a larger angle of emergence (51 °). Because of the double reflection, the light is weakened and so the secondary rainbow appears more faintly.

The rainbow does not fully enter the earthly world, but remains partly in a supersensory realm as an optical phenomenon without matter or energy. It really exists only for observers and only for observers individually - in this way it expresses its most profound significance: its relationship to the human `I'. Every person sees their own rainbow; even a neighbour, standing close by, sees a different arc. Therefore, there is no objective rainbow since one and the same bow cannot be seen or photographed from two places.

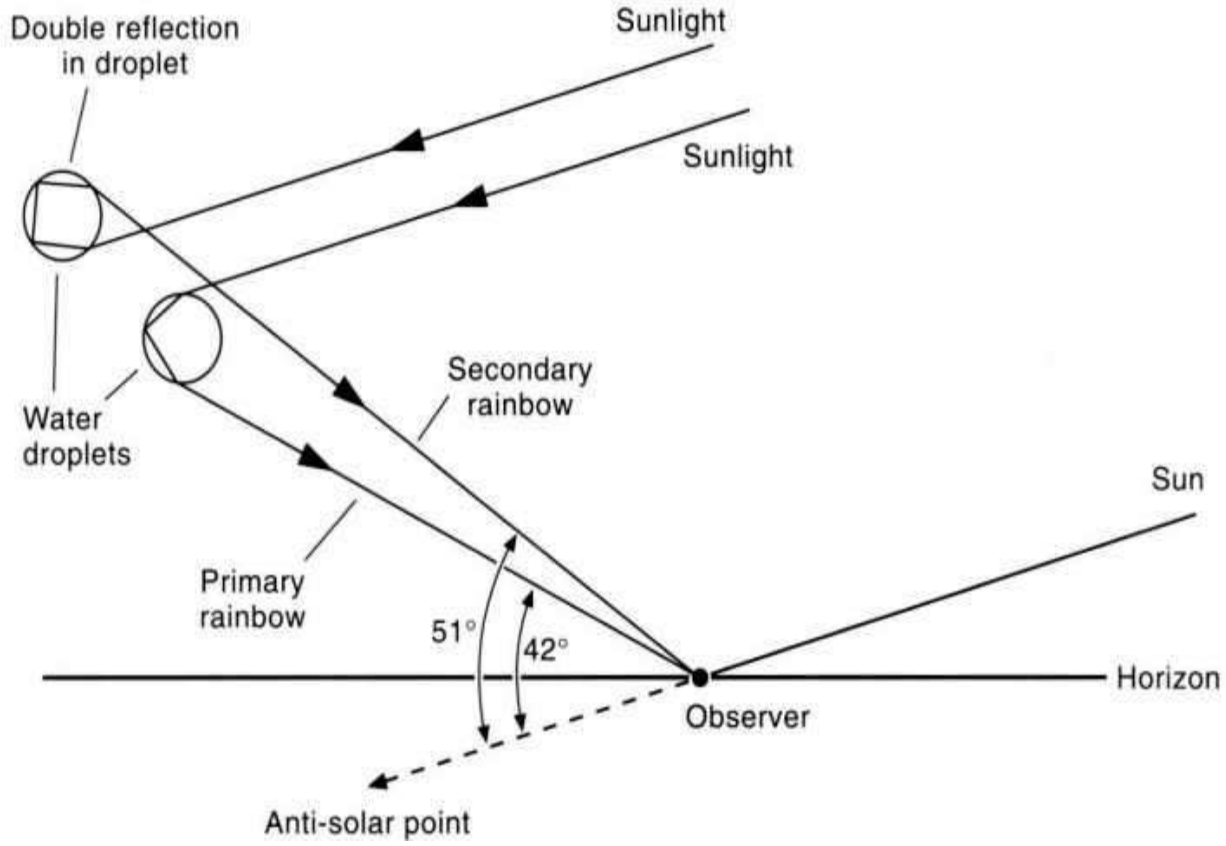


Figure 26. Formation of a primary and secondary rainbow.

In this photograph sunlight and the aurora appear together. The sun follows its course below the horizon and casts its delicate colours over the earth. In the heights, auroral bands have formed like kinds of clouds. Therefore the aurora shining on its own account can also be illuminated by the sun.

When the aurora has passed its highest point - often with the formation of a corona - a quiet period ensues. Individual patches of light and colour, at various places in the sky, call to mind the aurora's widespead curtains. These coloured clouds can linger quietly in the sky for several hours. In this photograph they are reflected with the stars in a quiet expanse of water.

In the Old Testament the rainbow was used as the sign of a new start after the Flood; the expression of a contract between God and humankind:

> I will remember my covenant which is between me and you and every living creature of all flesh; and the waters shall never again become a flood to destroy all flesh. When the bow is in the clouds, I will look upon it and remember the everlasting covenant between God and every living creature of all flesh that is upon the earth. I

In re-orientating themselves, human beings looked to the rainbow in order to proceed correctly on their way. While earlier peoples had looked to the planetary gods, especially the sun-god, later people looked to the sun itself, and above all to its rising. A particular group of human beings now began to look westward to the rainbow, which stood high in the morning sky before sinking down. If we consider the new beginning after the Flood, we see that in looking west this particular portion of humanity evoked the great cultural evolution that was to follow from east to west. The image of the rainbow descending in the morning pointed to a higher principle descending to earth, and with this outlook on the future, the Rainbow Epoch began.

Compared to lightning the rainbow has a completely different effect; the calm, shining bow of colour allows total freedom. It is not connected to any expression of will, nor does it present any movement that compels the observer to focus on any particular aspect of experience. The rainbow is totally at peace and inspires wonder and awe, and the beginnings of thought and love. Faced with the colour spectrum, man must develop thoughts freely of his own initiative. In this respect, the rainbow inspires and motivates him to adopt this thinking activity. From this perspective one can see that in history the Greek world was the genuine rainbow-culture of humanity. Philosophy arose from wonder at colourful phenomena, and love of the earth emerged from admiration of the sensual world. One gets a complete picture of the Greek rainbow-culture only when, to the abstract images of colourless white pillars, one adds the intensive colour with which these Hellenic buildings were painted. It was a joyful marriage with the colour spectrum.

However, this phenomenon should not be understood only in relation to the world of the senses, as in the case of the Greeks, it should be seen as the result of the soul's union with the earth in an individual human being. This

development had its beginning with Christ's resurrection. In the Isenheim altar picture, the painter, Matthias Grunewald (c.1460-1528), represented the resurrected Christ rising from the earth in the darkness of night, surrounding him with a radiant colour-aura through which the soul-power of the resurrection is conveyed to the spectator. In this depiction the rainbow's original promise has been attained.

When, after the Flood, the rainbow was given as the covenant between God and the human world, mankind also received the image of this future being of Christ, the Son of Man as the creator-spirit, which is concealed in every genuine sevenfold image. The seven colours of the rainbow reflected the many sevenfold groupings of our world: seven days of Creation; seven classical planets; seven weekdays; seven notes of the scale.

Aurora

Lightning and rainbows are generally well-known. On the other hand the aurora has remained almost unknown, and mysterious for most people. Even today, the aurora is not fully explained.

Moving to higher latitudes we find the aurora replacing the rainbow in the same way that the latter replaced lightning on leaving tropical regions. The rainbow appears, generally, in the hours of the late afternoon; the auroral display begins in the early evening. Beginning with the stationary auroral arc, it develops to the oscillating band of the northern lights. Movement arises, increasing in intensity until the whole sky is filled with draperies and curtains, finally culminating in the corona; in fading it disintegrates. The colours present in the static rainbow are liberated in the auroral display.

In contrast to lightning and rainbow, the extent of the phenomenon is immense; neither lightning nor rainbow is visible from outer space, but the aurora is. A lightning storm or rainbow can be seen from a locality on earth as a self-contained phenomenon. The entire spatial extent of the aurora can be grasped only by many observations over wide areas. Only recently could it be photographed by satellite from space, which revealed the aurora as a vast structure.

Lightning corresponds to a realm that is not directly connected with the

sun; it appears by day or night quite independently of light. The rainbow is caused by sunlight weaving in earth's atmosphere, and therefore only appears during the day. The origin of the aurora, however, is concealed in the earth's invisible magnetosphere, influenced by the sun and the solar wind. Like lightning, it is independent of light and darkness, but is, at the same time, a direct expression of terrestrial and solar energies. In lightning, these exertions are discharged in chaotic eruption. The rainbow shows no such energies. During an auroral display, powerful forces are gradually released in a perceptibly structured and mobile process.

In a spatial context, lightning appears as a one-dimensional event; a jagged structure seeking its course as a path of light, rapidly tearing itself loose from any orientation in space. The rainbow is quite different, standing unequivocally in terrestrial space, but is lacking the third dimension. The aurora embraces the whole of space, extending in three dimensions.

As the northern lights cannot be perceived in their entirety by just one observer, we are challenged to widen our consciousness to embrace the whole context of the earth and of the planets. With this wider perception the aurora can be interpreted as an expression of the Holy Spirit; both have always been hidden and unknown in historical periods of human evolution. Before the Christian era the Spirit could only be located in the world beyond, and since that time has only slowly penetrated human experience. Likewise, the aurora rarely revealed itself to mankind; it is only in the twentieth century, when humanity became a comprehensive and interrelated society, that the aurora has come into human awareness. It mirrors the earthly events of Pentecost bearing essential marks of this incident within itself; the colours of the aurora blaze over the earth, recalling the tongues of flame above the Apostles' heads when they experienced the original Whitsun.

Lightning, rainbow and aurora thus mirror the interaction of the Trinity within the earth's environment. Lightning expresses divine forces from the past, and the sustaining Father God. The rainbow exemplifies the image of the human `I' that finds true expression in Christ. The Holy Spirit is expressed through the activities of the aurora, and which reveals an apocalyptic future.

After watching the aurora borealis on many separate occasions, Fridtjof

Nansen mused:

> I have never been able to grasp the fact that this Earth will some day be spent and desolate and empty. To what end, in that case, all this beauty, with not a creature to rejoice in it? Now I begin to divine it. This is the coming Earth `here are beauty and death.'2

The aurora is a unique symbol of our present and our future.

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* Named after the English physicist Edward W. Maunder (1851–1928), who was superintendent of the Solar Department of Greenwich Observatory and who dedicated himself particularly to researching this calm phase of the sun.

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